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# NAVAL POSTGRADUATE SCHOOL

## Monterey, California

SPECTRUM RECEIVER AND SIGNAL SELECTION UNIT
DESIGNS FOR THE NAVAL POSTGRADUATE SCHOOL
SATCOM SIGNAL ANALYZER

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Project Report

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

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## ABSTRACT

The design and construction of a Signal Selection Unit and four Spectrum Receivers for use in the Naval Postgraduate School's SATCOM Signal Analyzer are presented. The purpose of the SATCOM Signal Analyzer is to provide high-speed spectrum analysis and characterization of the outputs of UHF communication satellite transponders in orbit. It is constructed around a PDP-11/34 minicomputer which provides the necessary control for most of the equipment of the system. Extremely accurate frequency measurement is provided by the frequency receivers and signals for multi-channel spectrum analyses are provided by the Spectrum Receivers. The Signal Selection Unit routes signals to the Spectrum, AM/FM, and Frequency Receivers. This report documents the design and development of the Spectrum Receivers and the Signal Selection Unit.

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# I. INTRODUCTION

## A. BACKGROUND

The Satellite Communications Laboratory of the Naval Postgraduate School has been tasked by PME-106-1 of the Naval Electronic Systems Command to design and construct a prototype SATCOM Signal Analyzer. This unit will be used to monitor authorized users of the Navy's SATCOM resources and to analyze RFI sources. Digital techniques for spectrum analysis and frequency measurement are to be used to interface directly with NAVCOMSTA facilities. The primary control interface with the human operator is a standard CRT by Hewlett-Packard, with a Carroll Manufacturing touch panel capability. The system shall have automatic as well as manual modes of operation.

The proposed prototype configuration for the SATCOM Signal Analyzer is shown in Figure 1.1. The four spectrum receivers' design and construction are contained in Chapter II. The Test Transmitter provides an uplink with frequency and calibrated ERP under computer control. This unit's primary function is to provide an automatic uplink power measurement by inserting a carrier offset from center frequency. With the use of the spectrum analyzer, RFI can then be determined to be coming either through the satellite's transponder or from a local source. The X-Y Modulation Display provides a signal voltage display to an oscilloscope showing inphase and

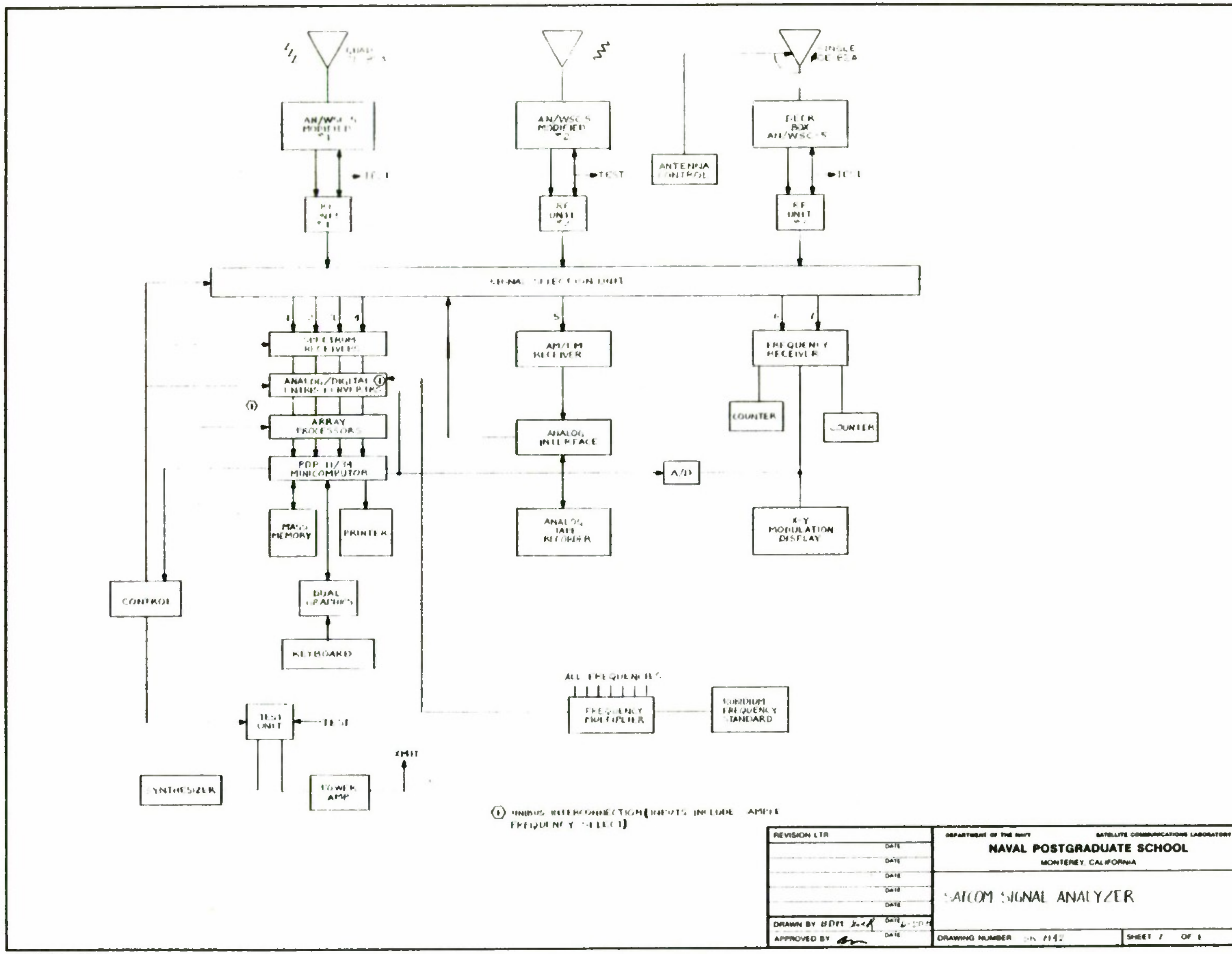



Figure 1.1

SATCOM SIGNAL ANALYZER

quadrature components. Digital conversion will be used to present this data to the hard copy unit. The Signal Selection Unit is contained in Chapter III. Phase-locked Receivers provide precise frequency measurement and stabilization of the modulation display. Precise frequency measurement is made possible through the use of a Rubidium Standard. This report will present the Spectrum Receiver and Signal Selection Unit designs for the SATCOM Signal Analyzer.

## B. SPECIFIC GOALS

The specific goals in the design and development of the SATCOM Signal Analyzer are: (1) to provide real-time, multi-channel monitoring of satellite downlink signals with RFI present, and (2) to provide the necessary Research and Development of signal frequency measurement techniques and equipment for use in a follow-on version of the Fleet Satellite Monitoring System (FSM) presently in use at Naval Communications Stations to monitor the operation of the GAPFILLER and FLTSAT satellites [1].

## C. SCOPE OF THIS PROJECT

This report's documentation is in two parts. The first is the design of four spectrum receivers providing the capability of multi-channel monitoring of downlink signals of UHF communications satellites. The second is the design and construction of the Signal Selection Unit which directs signals from seven different sources to the Spectrum, AM/FM and Frequency Receivers, and the Test Unit.

## D. APPROACH

The block diagram for Spectrum Receivers SR1 through SR4 is shown in Figure 1.2. All four spectrum receivers are identical and provide four selectable $\pm$ .25 dB bandwidths of 600, 100, 30, and 3 kHz. Following the filter bank is significant signal amplification and downconversion to baseband for sample/hold and A/D conversion. An output is provided to an oscilloscope for monitoring the signal level in each receiver. The analog tape recorder can be used for playback of recorded signals for analysis and training. The combination of high amplification and programmable attenuation at the lower end of the receiver diagram provide for a large dynamic range of input signal power levels. Intermodulation is reduced also with the large dynamic range.

The Signal Selection Unit block diagram is shown in Figure 1.3. Here the downlink signals at IF, tape playback, and transmit signals are directed to the Spectrum Receivers, AM/FM Receivers, Frequency Receivers and Test Unit. Switching is provided by a series of 6-way, 4-way and 2-way Lorch Electronics solid state, TTL compatible switches.

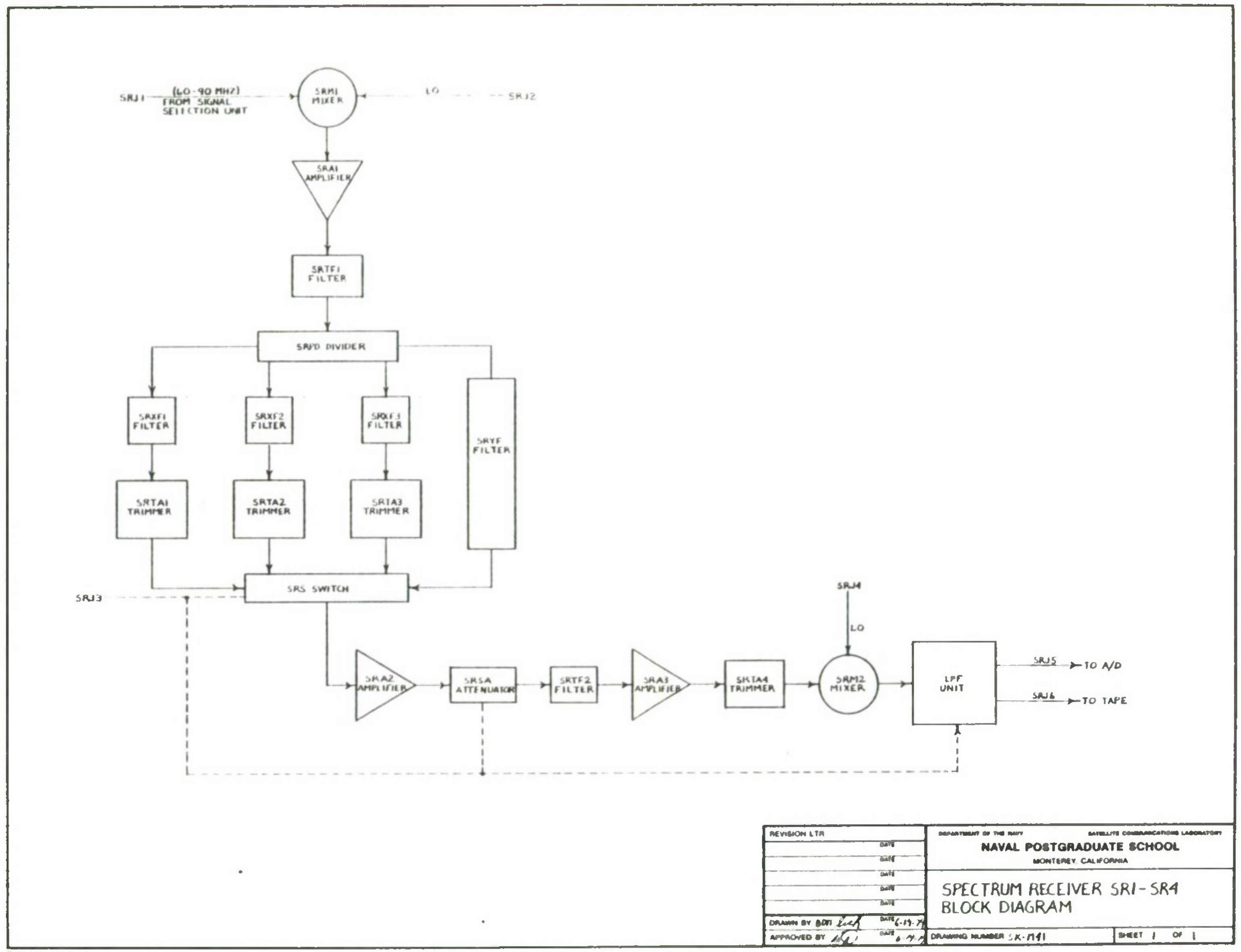



Figure 1.2

SPECTRUM RECEIVERS

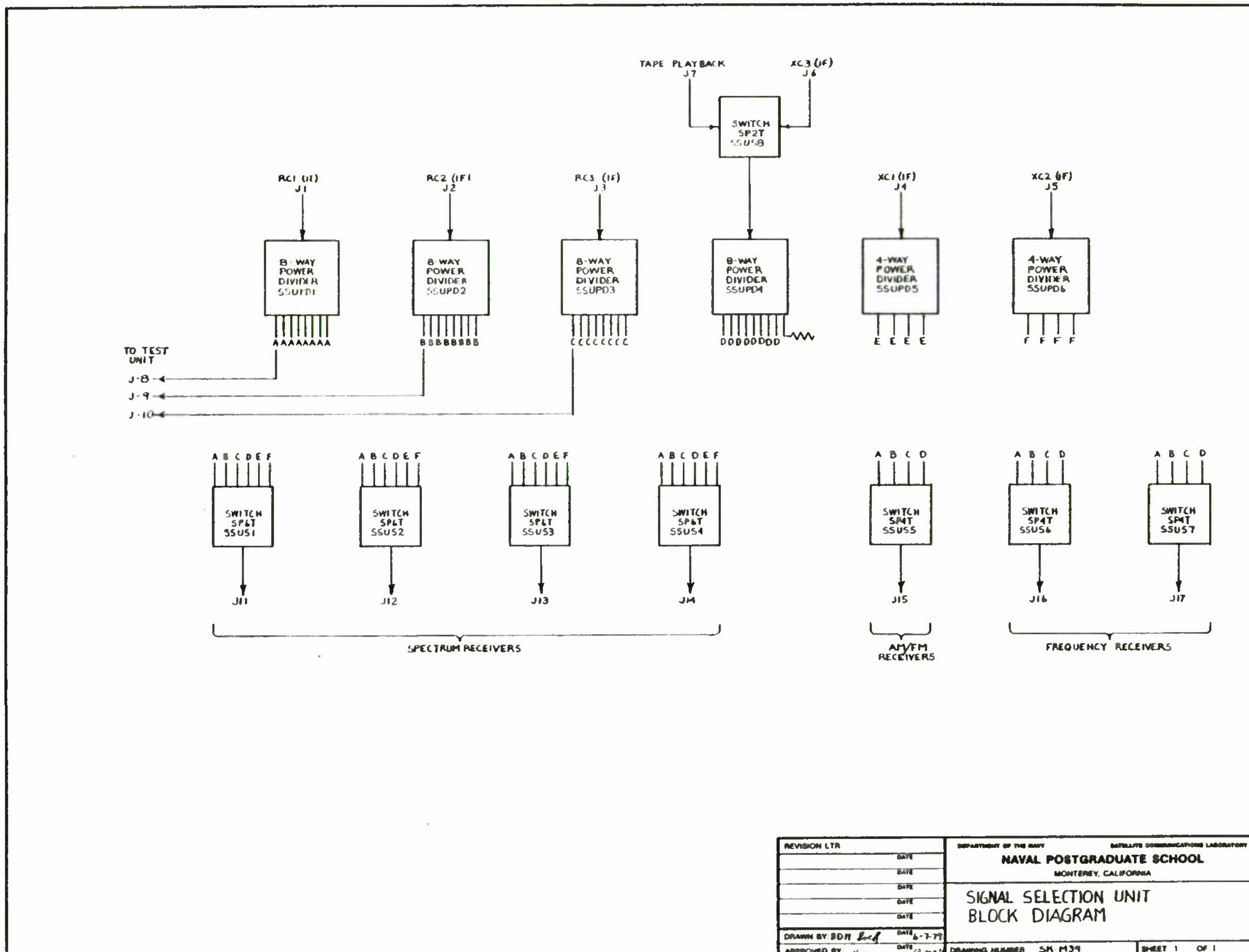



Figure 1.3

SIGNAL SELECTION UNIT BLOCK DIAGRAM

# II. SPECTRUM RECEIVERS SR1 THRU SR4

## A. GENERAL

The component parts of the Spectrum Receivers are to be mounted on 3/16" thick aluminum panels which are in turn mounted on a swing gate in the back of standard instrumentation cabinets manufactured by Zero Corporation. Interconnections between components are made with RG-223 coaxial cable and SMA fittings. The selection of component parts for the Spectrum Receivers SR1 → SR4 experienced many iterations during this initial design. Numerous configurations were compared on the basis of cost, complexity, TTL compatibility, system noise temperature, and 1 dB compression levels. The final version is presented with inside and outside modular placement of components shown in Figures 2.1 and 2.2. Some components on the inside are mounted on a 2-½" stand-off for space and heat dissipation considerations.

The function of the Spectrum Receivers SR1 thru SR4 is to receive the downconverted IF of 60 - 90 MHz, downconvert again using a synthesized local oscillator from $\{(90 - \Delta) - (120 - \Delta)\}$ MHz producing the second IF of $(30 - \Delta)$ MHz. $\Delta$ is determined for each filter bandwidth of the main filter bank. It is the frequency difference between 30 MHz and each filter's center frequency. The $\Delta$'s for crystal filters 1 → 3 and the L.C. filter are 4.5, 34, 105, and 500 kHz, respectively. This second IF is filtered by one of four selectable high "Q"

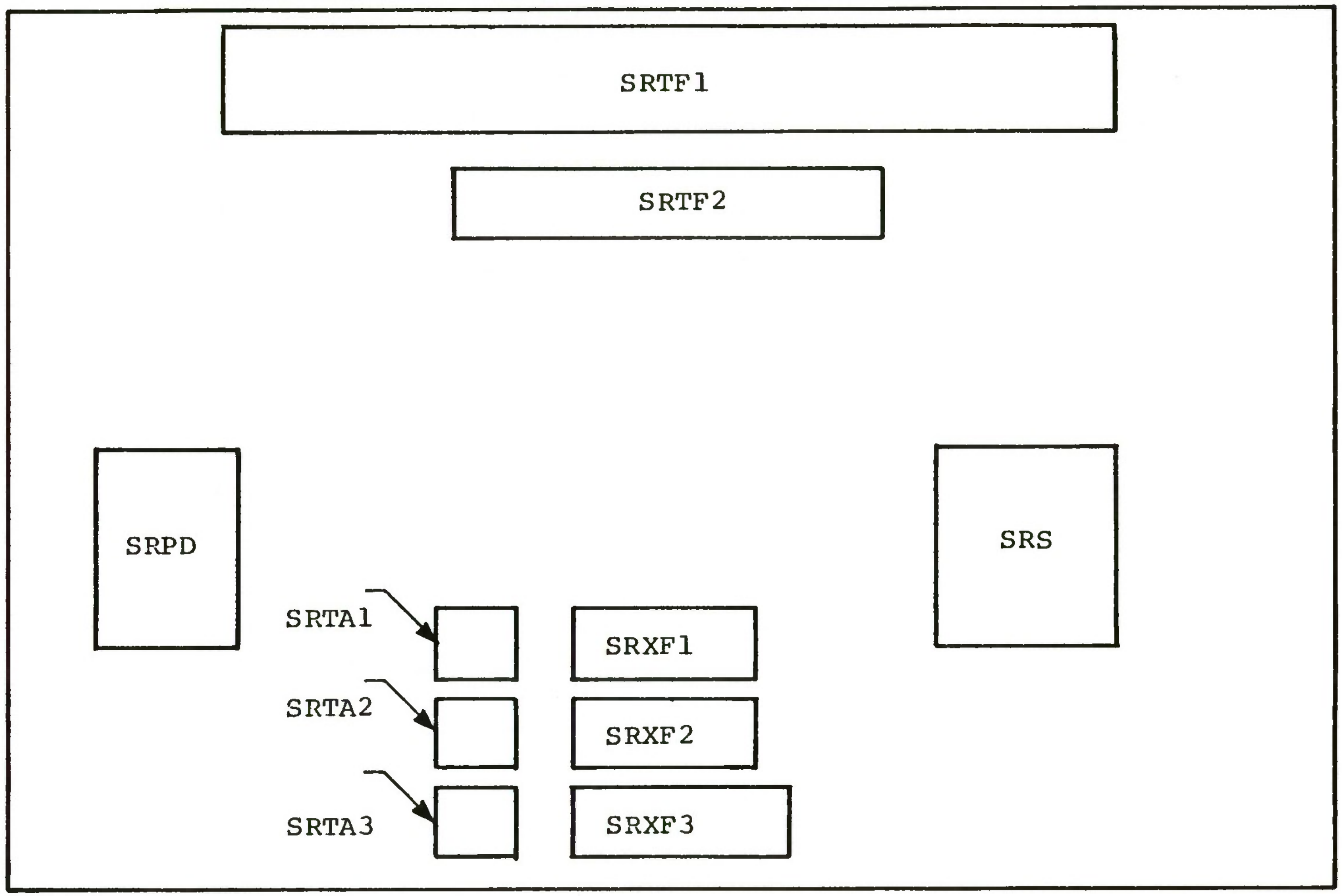



Figure 2.1

MODULAR PLACEMENT OF COMPONENTS OF SR1 → SR4 (outside)

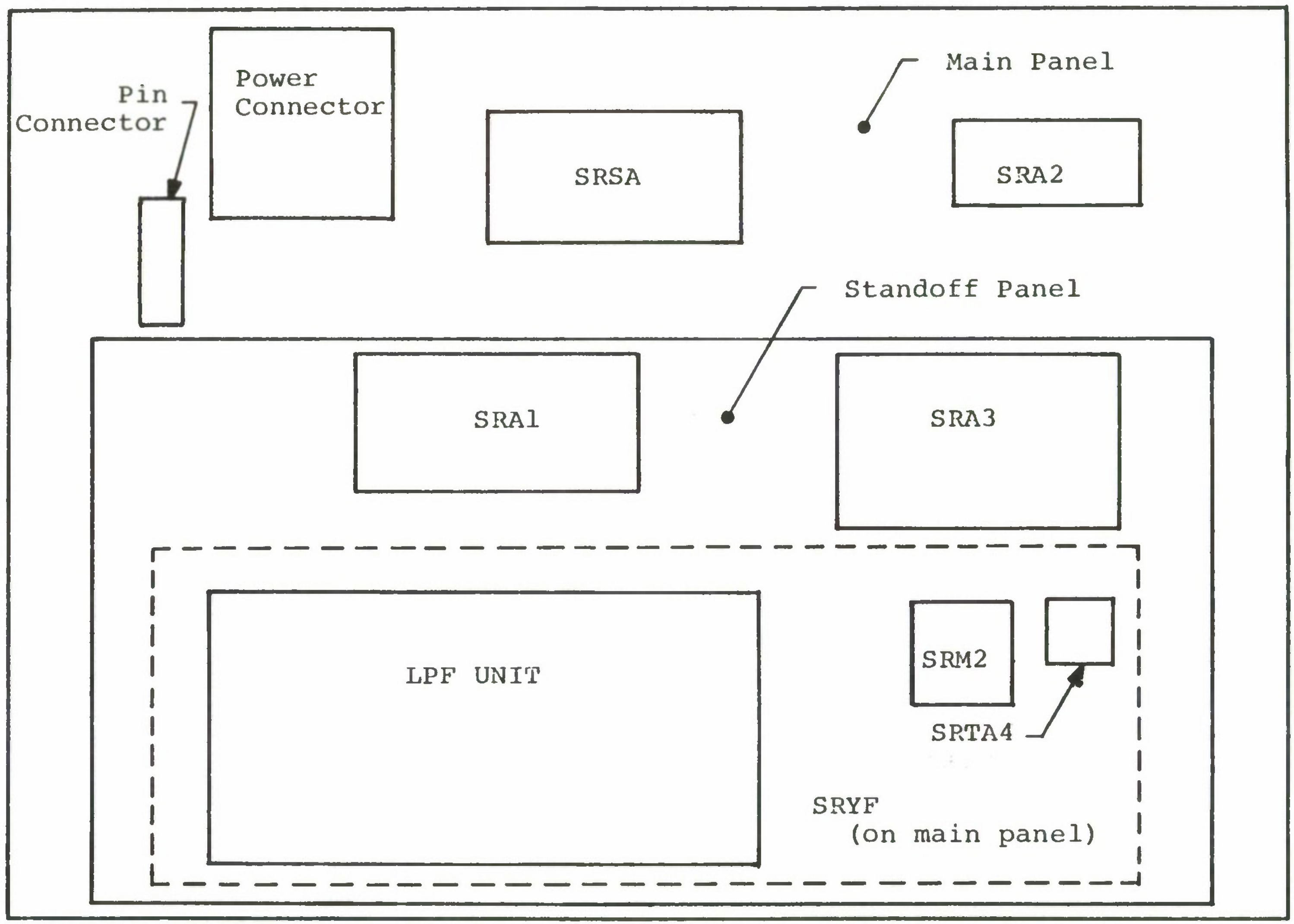



Figure 2.2

MODULAR PLACEMENT OF COMPONENTS OF SR1 → SR4 (inside)

filters, and finally converted to baseband for (1) subsequent analog-to-digital conversion for spectrum analysis, and (2) provision of predetection IF to the analog tape recorder. Any one of four selectable IF bandwidths are chosen after the main filter bank of three Damon Crystal filters and one Lumped Component (LC) bandpass filter by K & L Microwave. The filter bank and selector switch are shown in Figure 2.3. Table I shows the main filter bank's passbands and corresponding sampling frequencies.

## B. DESIGN CONSIDERATIONS

### 1. Crystal and L.C. Filter Selection

The three crystal filters following downconversion to approximately 30 MHz provide desired passbands of 3 kHz, 30 kHz, and 100 kHz. The 0.5 dB bandwidth specification for ordering the filters were 4 kHz, 32 kHz and 110 kHz respectively, to account for center frequency drift range due to temperature, atmospheric variations, and aging. The wider 0.5 bandwidths also provide for flatter passbands of interest. The different crystal filter passbands allow for spectrum analysis with three degrees of frequency resolution, the narrowest passband providing the best resolution. The narrowest bandwidth obtainable at a center frequency, $f_c$, of 30 MHz is 3 kHz requiring a high "Q" of

$$\frac{30\ \text{MHz}}{3\ \text{kHz}} = 10^4 .$$

There is a restriction to the highest "Q" obtainable due to a roll-off of 20 dB/decade for each pole in a network. The

TABLE I

MAIN FILTER BANK BANDWIDTHS

| FILTER | CENTER FREQ (MHz) | SAMPLING FREQ. | BANDWIDTH |
|---|---|---|---|
| SRCF1 | 29.9955 | 18 kHz | 4 kHz |
| SRCF2 | 29.966 | 136 kHz | 32 kHz |
| SRCF3 | 29.895 | 480 kHz | 110 kHz |
| SRYF | 29.5 | 2.0 MHz | 600 kHz |

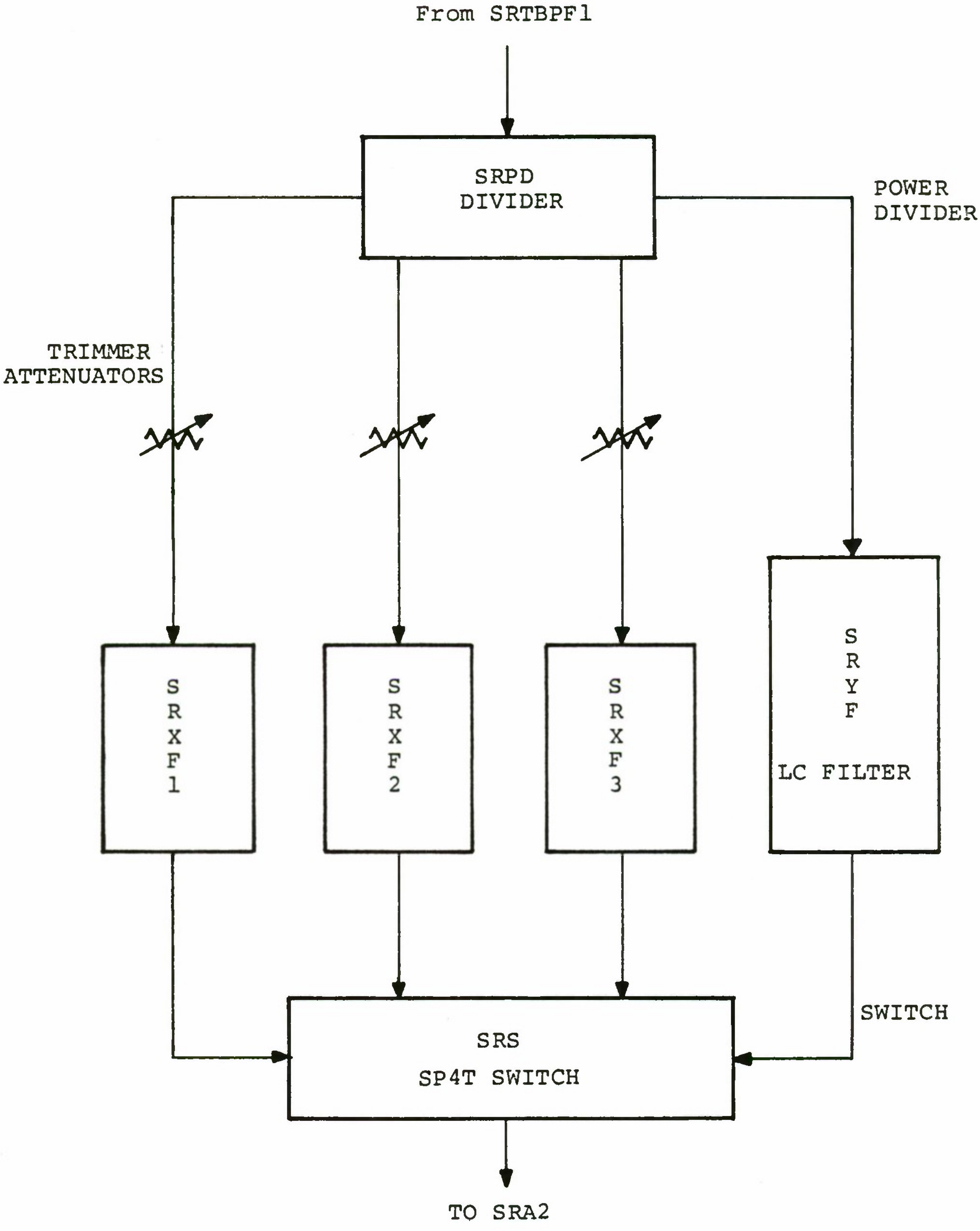
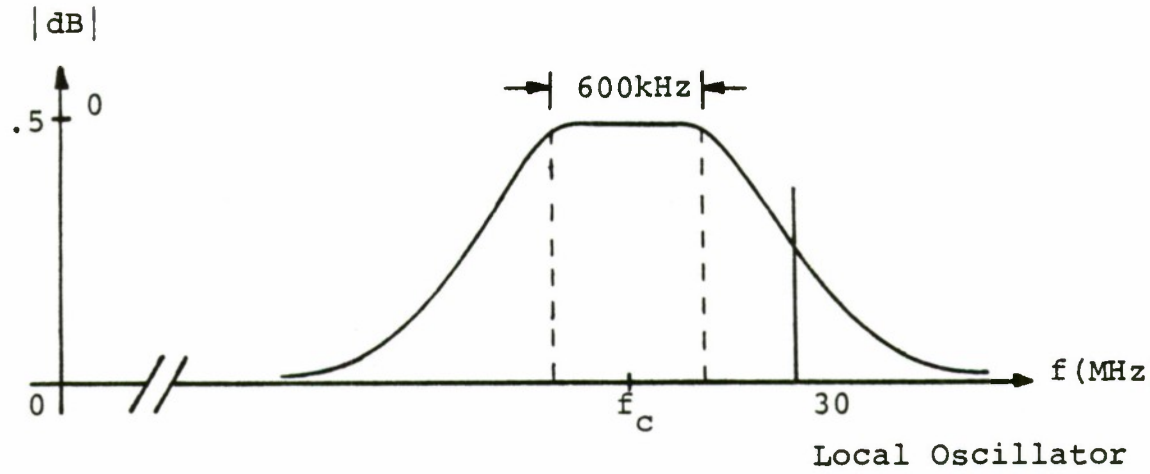



Figure 2.3
FILTER BANK AND SP4T COAXIAL SWITCH

addition of poles increases the roll-off with the design trade-off of adding insertion loss. Crystal filters were selected for their outstanding characteristic of very high stability of electrical parameters over long periods of time under variable environmental conditions. For maximum power transmission, the impedance requirement was set at 50 ohms for input and output. The maximum acceptable input power level is +15 dBm. Between +15 and +20 dBm there will be significant reduction in passband parameters. Above +20 dBm permanent damage will result. The sampling frequencies for the crystal filters are shown in Table I, the highest one approaching the maximum sample rate (2.22 MHz) of the A/D converter [2].

The L.C. bandpass filter SRYF is a lumped twelve-section filter manufactured by K & L Microwave, Inc. Its passband is centered at 29.950 MHz, with a 0.5 dB bandwidth ($\pm$ .25 dB ripple) of 600 kHz, providing a 50 kHz margin on either side of FLTSATCOM's DOD wideband 500 kHz channel. Although the maximum sample rate of the A/D converter is 2.22 MHz, it was decided to utilize 2.0 MHz as the highest sampling frequency. With this reduced sampling rate, slightly more aliasing is expected. Figure 2.4 shows a maximum interference level of -35 dB due to aliasing.

The leading tubular filter SRTF1 is a six-section filter by K & L Microwave, Inc., and has a 0.25 dB bandwidth of 800 kHz centered at 29.6 MHz. It has a 60 dB bandwidth of 6 MHz and functions primarily to pass desired frequency



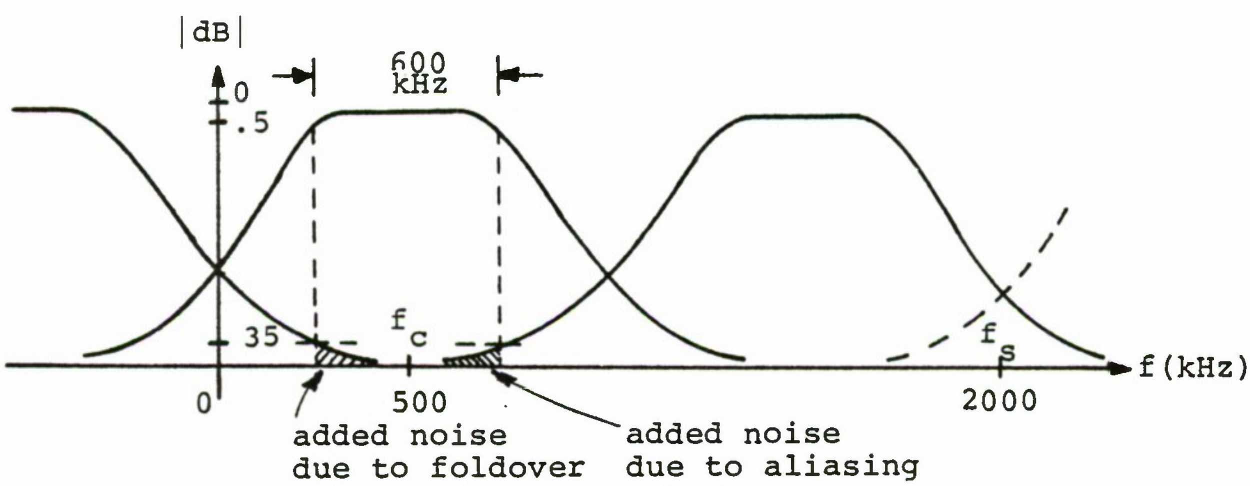




Figure 2.4

DOWNCONVERSION AND SAMPLING

components and reject the spurious responses of the crystal filters. Folding was not required as its overall length, including SMA female connectors, is under 16 inches. Its passband spans all of the filter passbands in the main filter bank as shown in Figure 2.5

The final tubular filter is a simple two-section bandpass by K & L Microwave, Inc., and has a center frequency at 29.6 MHz with a 3.0 dB bandwidth of 3.0 MHz. It functions to reduce the wideband noise over 0 to 500 MHz generated by the preceding amplifier.

All the tubular filters have a mounting style "C" which taps part of the filters' braces precluding the requirement for external mounting brackets. Insertion losses for each tubular filter is given by:

$$\text{insertion loss (dB)} = \frac{(\text{loss factor})(\text{number of sections} + .5)}{\text{percent bandwidth}}$$

Calculated insertion losses for filters SRTF1, SRYF, and SRTF2 are 3.5 dB, 9 dB, and 0.7 dB, respectively.

2. Anti-Aliasing Filters

Careful consideration with respect to unwanted additive noise due to foldover by SRM2 and aliasing was taken in the selection of the sampling frequencies, $f_s$. The $f_s$ for the narrowband filter was chosen to be 18 kHz to insure that the interference due to aliasing would be less than (-) 60 dB inside the passband. A very strong signal on the skirt of the passband would be attenuated by at least 60 dB when aliased. When the signal is sampled, the resultant spectrum is the

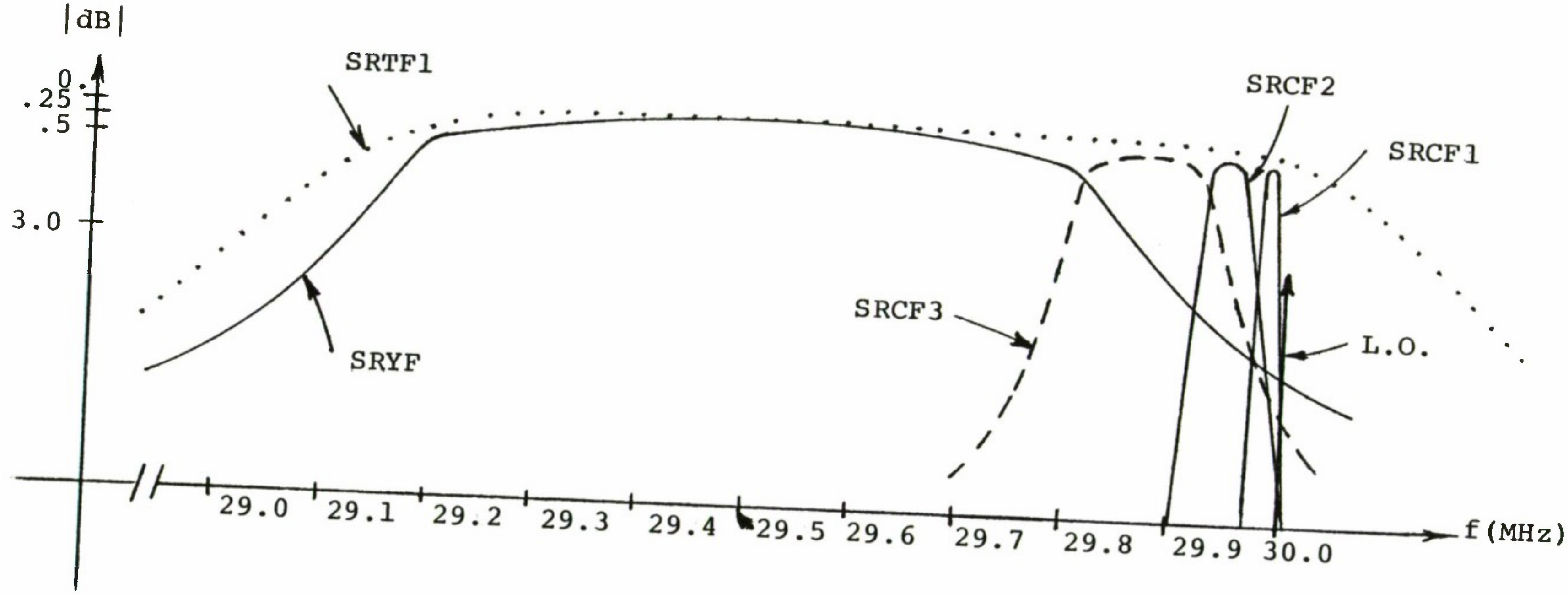



Figure 2.5

FILTER ENVELOPES

product obtained by convolving the signal-plus-noise spectrum and the sin x/x spectrum of the sampling waveform. This convolution results in the creation of new frequency components which are sums and differences of all frequency components in both spectra, including sums and differences of all harmonics of both signal and sampling waveforms. The noise frequencies that get through the filter will be mixed with the sampling-waveform frequencies. Some of the difference-frequency components will fall within the desired signal spectrum creating the aliasing errors. The cost or design trade-off to reduce aliasing errors is to either improve the stop band attenuation, increase the sampling rate, or use a combination of both.

The aliasing in the Spectrum Receivers is minimized through the use of the anti-aliasing low pass filters whose block diagram is shown in Figure 2.6. Figure 2.7 details the control connections between the Control Bus Board and the Spectrum Receivers. The flat cable from the Control Bus Board joins the 50-pin T & B/Ansley connector with mapping provided in Appendix B. The 50-pin ribbon is then split into four bytes, forming an interface panel. The four bypes lead from the interface panel, one to each of the Spectrum Receivers. On the 15-pin connector to each Spectrum Receiver are eight control bits on pins 1 through 8, two ground lines on pins 9 and 10, and +5 volts on pin 15. The selection of any one of the anti-aliasing filters is coincident with the selection of a corresponding filter in the main filter bank.

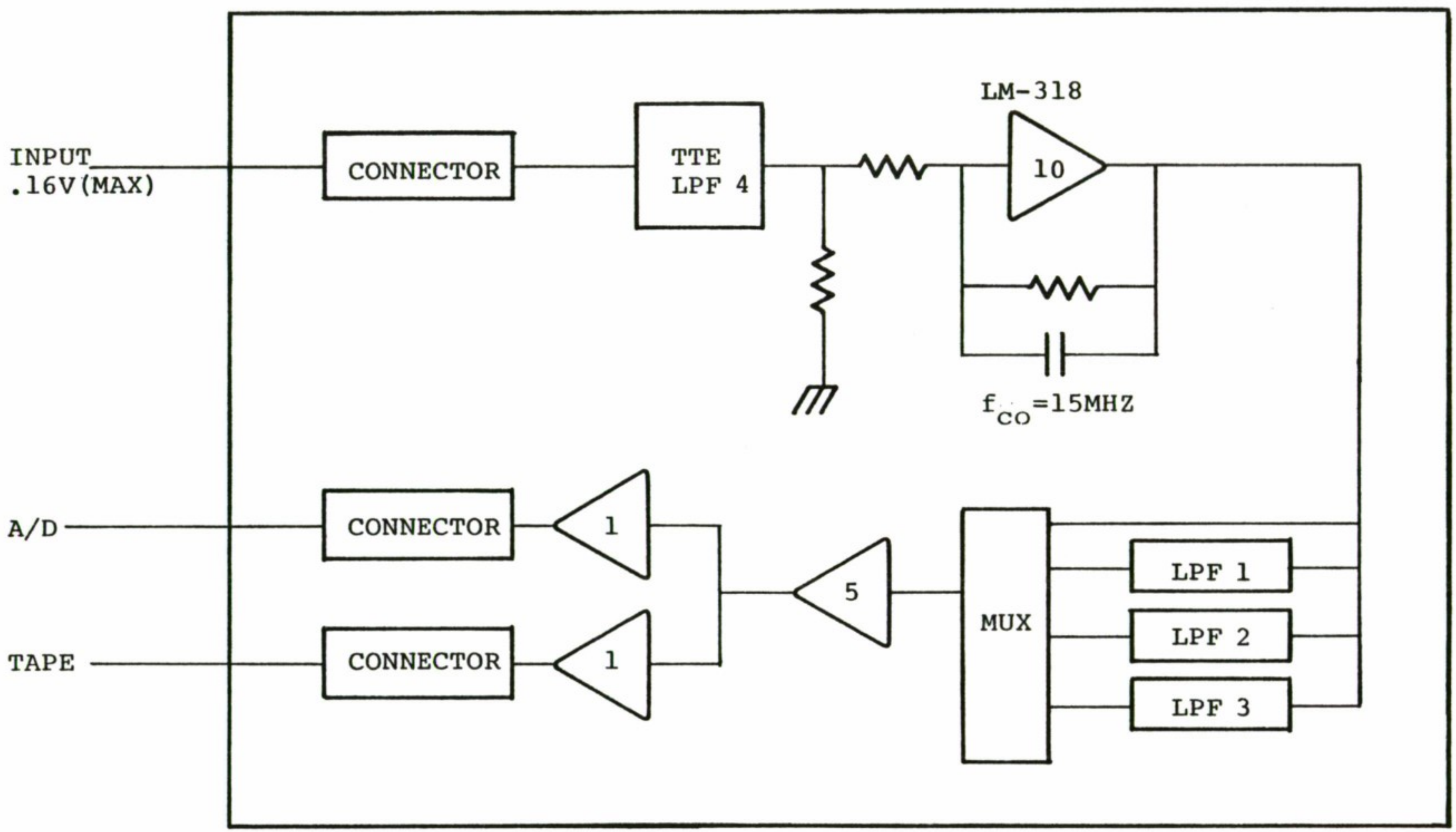



Figure 2.6

ANTI-ALIASING FILTER UNIT

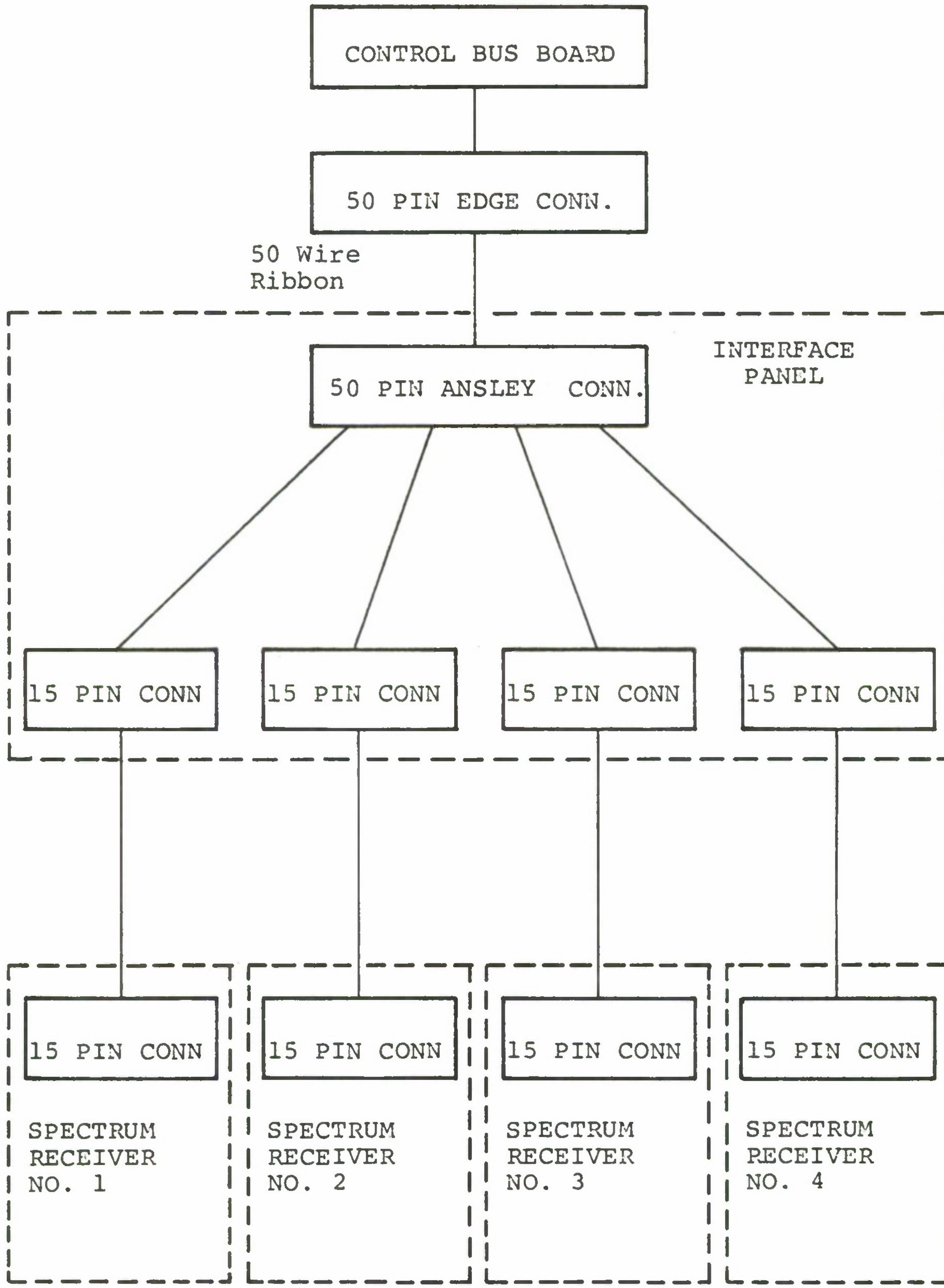



Figure 2.7

SPECTRUM RECEIVER CONNECTIONS

Program mapping for the selection of a desired bandwidth is presented in Appendix C. Appendix D shows the specification of each of the lowpass filters, SRLP1 through SRLP4. SRLP1, SRLP2, and SRLP3 are Butterworth filters in which the basic component is the Universal Hybrid Active Filter, Model FLT-U2, by Datel Systems, Inc. The block diagram for the FLT-U2 is shown in Figure 2.8. The external capacitors are used only if $f_{co} \leq 50$ Hz. The Butterworth function is achieved by the addition of the uncommitted operational-amplifier to the basic two-pole configuration of the FLT-U2. For all three Butterworths, the gain of the additional operational amplifier is one, and a "Q" of one was used even though an adjusted "Q" is calculated for the higher frequency cut-off filters. Resistor values were determined from formulas given in [4]. $R_1$ in all filters is 100kΩ. $R_2$ is open when using the inverting configuration

$$R_3 = \frac{100K\Omega}{(3.8)(Q)-1}$$

"Q" is increased by one percent at an $f_{co}Q$ product of $10^4$, and 20 percent at an $f_{co}Q$ product of $10^5$. $R_3$ is the "Q" determining resistor of the two pole portion of the FLT-U2. $R_4$ and $R_5$ are the frequency cut-off determining resistors and are normally but not necessarily equal.

$$R_4 = R_5 = \frac{5.03 \times 10^7}{f_{co}}$$

The natural frequency varies as $\sqrt{R_4 R_5}$, so long as the product or $R_4$ and $R_5$ remain the same the natural frequency is

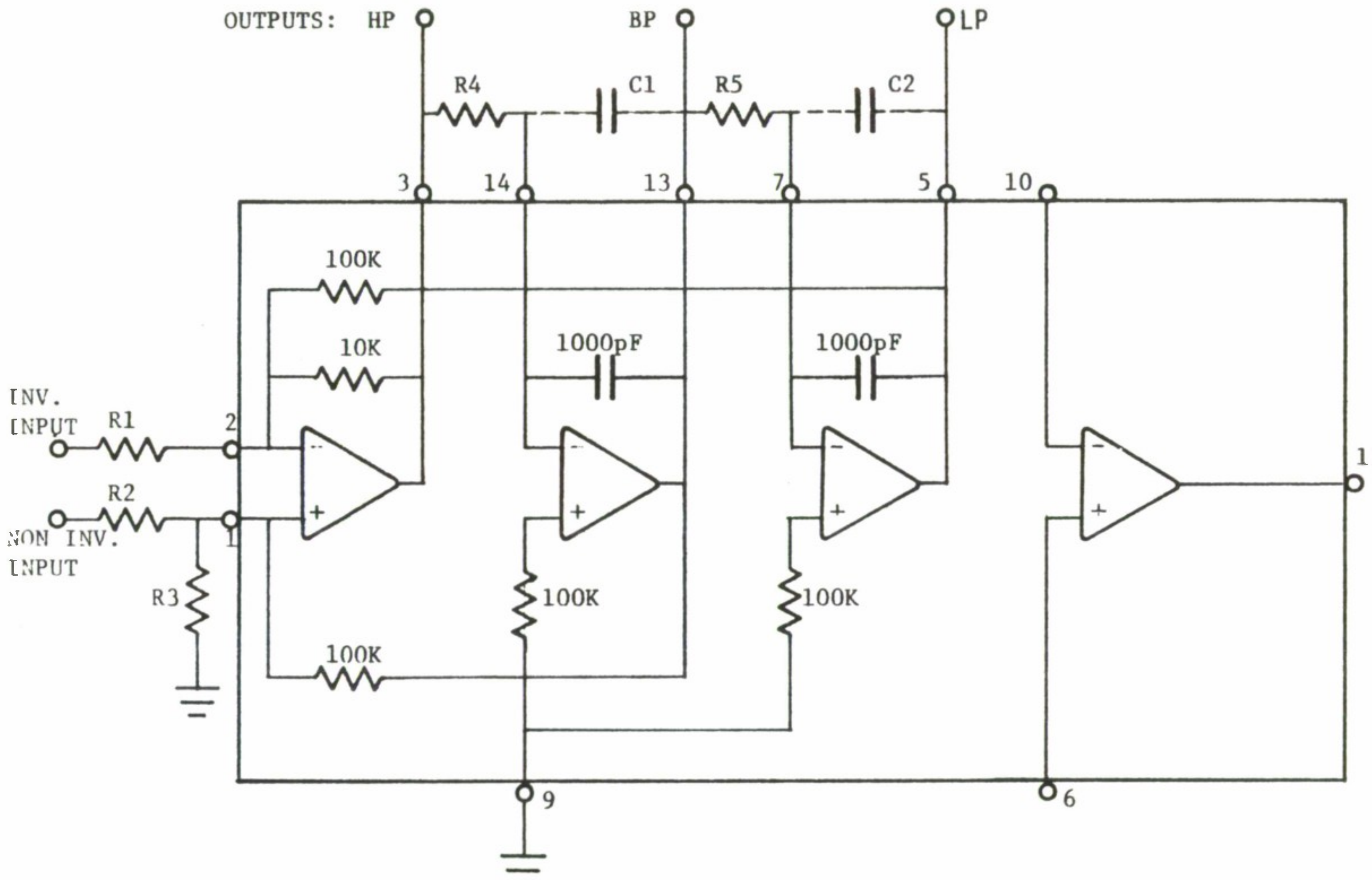



Figure 2.8

BLOCK DIAGRAM FOR FLT-U2

not changing. $R_6$ and $R_7$ are the gain determining resistors of the uncommitted amplifier. With a voltage gain of one

$$\frac{R_6}{R_7} = 1, \; R_6 = R_7.$$

$R_6$ and $R_7$ were arbitrarily chosen to be 10k$\Omega$; $R_8$ is taken to ground and is determined by the parallel combination of $R_6$ and $R_7$.

$$R_8 = \frac{R_6 R_7}{R_6 + R_7}$$

The cut-off frequency of the uncommitted operational amplifier used in the inverting configuration is:

$$f_{co} = \frac{1}{2\pi \; R_7 C}$$ and, therefore,

$$C = \frac{1}{2\pi R_7 f_{co}} \; .$$

The use of the uncommitted operational amplifier in the inverting configuration is shown in Figure 2.9. The capacitance and resistive values for the three filters designed with the FLT-U2 are shown in Appendix E.

The cut-off frequencies were selected by adding twenty percent to the highest frequency component in the .5 dB bandwidth of the corresponding filter of the main filter bank and dividing this sum by 0.6. This insures providing .2 dB or less of flatness across the desired passband while attenuating those noise frequency components outside the passband aliasing.

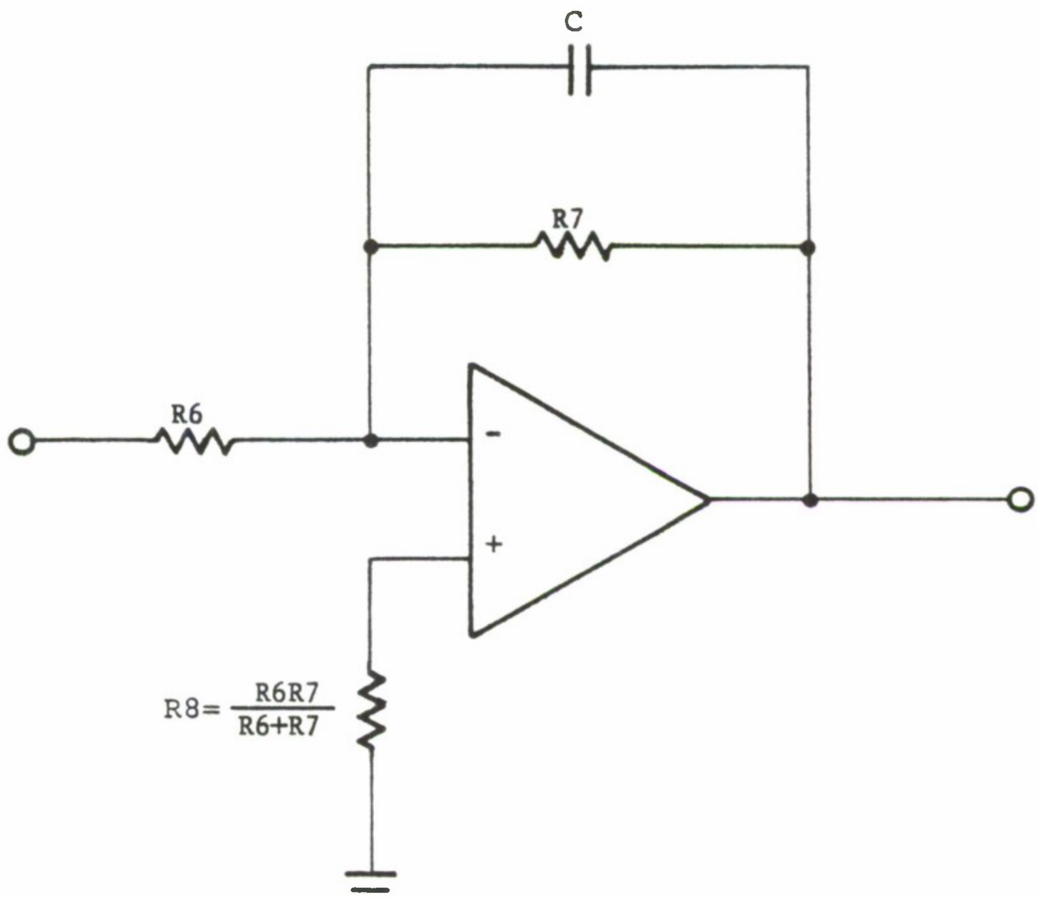



Figure 2.9

UNCOMMITTED OP-AMP

The factor 0.6 was determined from the following discussion. Comparing the standard two pole transfer function of

$$H(s) = \frac{K\omega_o^2}{s^2 + \frac{\omega_o s}{Q} + \omega_o^2}$$

to the Butterworth transfer function of

$$H(s) = \frac{K\omega_o^2}{s^2 + \omega_o s + \omega_o^2} .$$

where K is an arbitrary time constant, we see that $Q = 1$. Normalizing around $\omega_o$, the addition of the third pole gives an

$$H(s) = \frac{\omega_o^3}{(s + \omega_o)(s^2 + \omega_o s + \omega_o^2)} , \text{ and}$$

$$H(j\omega) = \frac{1}{(1 + \frac{j\omega}{\omega_o})(1 + \frac{j\omega}{\omega_o} - \frac{\omega}{\omega_o})^2}$$

for $s = j\omega$. For $X = \frac{\omega}{\omega_o}$ the magnitude of the transfer function becomes

$$|H(j\omega)|^2 = -10 \text{ Log } (1 + X^2)\ (1 - X^2 + X^4)$$

For a normalized frequency of 1 ($X=1$), the magnitude of the transfer function is (-)3dB. A (-)0.2 dB value is obtained at a normalized frequency of 0.6. The 0.2 dB passband of this Butterworth model is therefore given by

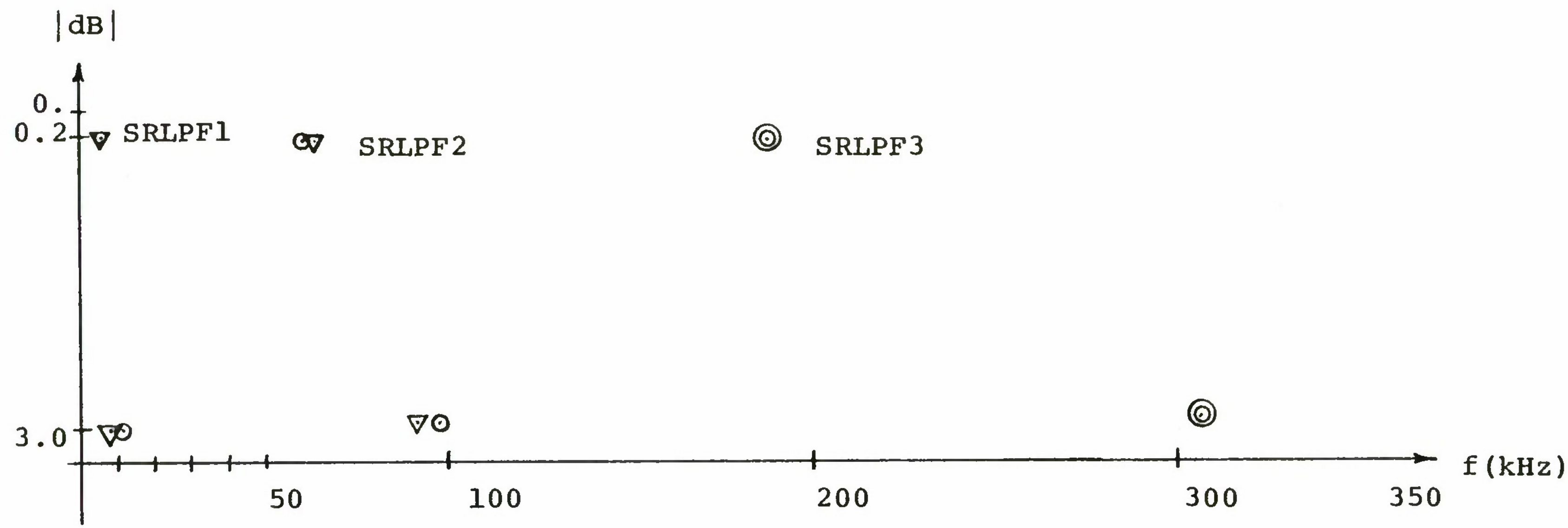
(0.6)(3 dB passband).

For the filters SRLPF1, through SRLPF3, the specified and observed bandwidths are given in Figure 2.10.

The fourth low pass anti-aliasing filter is made by TTE Miniature Filters. Its 0.2 dB bandwidth is 0 - 800 kHz, providing 3.0 dB of attenuation at 1.5 MHz and a minimum of 10 dB attenuation beyond 2.2 MHz. The Datel FLT-U2 could not be used for this filter because of the high frequency limitation in the FLT-U2.

3. Mixer Selection

The two mixers in the Spectrum Receivers are Merrimac double-balanced, medium level (+17 dB) mixers with minimum 1 dB compression points of +8 dBm. Specifications for the mixers are shown in Appendix F. Although designed for a local oscillator level of +17 dBm, they have a useful range of L.O. drive from +10.0 to +20.0 dBm without significant changes in the output power level. The L.O. drive levels into the Spectrum Receivers are nominally at +13 dBm and are provided by a Rockland synthesizer, model 5610A. The first mixer, SRM1 receives a selected IF signal via the Signal Selection Unit at a frequency of 60 - 90 MHz and maximum input power levels of -58.5 dBm for the downlink signal and +4.0 dBm for strongest out-of-band RFI. The -58.5 dBm input power level was determined using a -85 dBm downlink signal level at the receive antenna. The system gain to the input of the mixer is +26.5 dB. Similarly, the +4.0 dBm RFI signal level was determined by assuming the strongest allowable interference level of -22.5 dBm at the receive antenna. The strongest allowable RFI at




NOTE: ⊙ = specified
∇ = observed
◎ = specified (actual to be determined)

Figure 2.10

SPECIFIED AND OBSERVED PASSBANDS FOR SRLP1 → SRLP3

the antenna which the Spectrum Receivers can analyze without SRA2 going into saturation is -22.5 dBm. This input signal is mixed with the local oscillator at (90 - Δ) to (120 - Δ) MHz providing an output at (30 - Δ) MHz. Δ is defined for each filter bandwidth of the main filter bank as the frequency difference between 30 MHz and each filter's center frequency. The Δ's for crystal filters 1 → 3 and the L.C. filter are 4.5, 34, 105 and 500 kHz, respectively. The decision to use the L.O. frequency offset from 30 MHz by a factor of ΔMHz allows the L.O. in mixer number 2, SRM2, to be at 30 MHz and precludes the need for four L.O. frequencies, one for each filter of the main filter bank.

The second mixer in the Spectrum Receivers has as its strongest input signal power level +5 dBm which will provide a mixer output voltage level of .16VRMS. This voltage is required at the input of the anti-aliasing filters in order to provide a peak voltage level of 10 volts to the input of the A/D converter board. The input signal frequency is at (30 - Δ) MHz and is downconverted to baseband by mixing it with a 30 MHz local oscillator.

The noise figure of each mixer is specified as conversion loss plus 1 dB or about 8.5 dB. For the device's noise temperature contribution see Table II.

4. Amplification Chain

The received signal into the SR1 → SR4 Spectrum Receivers must be amplified and downconverted to baseband for analog-to-digital conversion. The resultant signal has as a maximum voltage 10 volts as described in [2].

TABLE II

SUMMARY OF NOISE TEMPERATURE CALCULATIONS

| Componant(s) | Gain or Loss (dB) | Gain (dB) of system to that point | Noise Figure (dB) | Noise Temperature Contribution of Componant (K) | System Noise Temp. (K) to that point |
|---|---|---|---|---|---|
| SSUPD1/SSUS1/ SRM1/Cable | L=19.0 | 38.0 | 20.0 | 4.5 | 550 |
| SRA1 | G=+22 | 19.0 | 3.5 | 4.5 | 554.5 |
| SRTF1/SRPD/ SRXF1→SRXF3/ SRYF/SRS | L-20.2 | 41.0 | 20.2 | 2.4 | 559.0 |
| SRA2 | G=18.5 | 20.8 | 5.5 | 6.1 | 561.4 |
| SRSA/SRTF2 | L=18.3 | 39.3 | 18.3 | 2.3 | 567.5 |
| SRA3 | G=80 | 21.0 | 3.5 | 2.9 | 596.8 |
| | | | | | $\approx$ 600 |

The amplification chain for the Spectrum Receivers SR1 → SR4 is shown in Figure 2.11. The SRA1 is a QB-300, by Q-Bit Corporation, with a gain of 22 dB and a 1 dB compression point of +22 dBm. It is followed by 20.2 dB of loss in the SRTF1, 4-way divider, and filter network. SRA2 is an Anzac amplifier model AM-105, with a typical gain of 18.5 dB and a 1 dB compression point of +16 dBm. It is followed by a 4-step variable attenuator that can be varied in attenuation from 0 to 88 dB in 8 dB increments. The purpose of this solid state step attenuator by DAICO Industries, is to allow the operator to look at very strong signals up to -22.5 dBm and prevent SRA2 from going into non-linear operation. It is nominally set at -16 dB to provide 16 dB of dynamic range of the input downlink signal. The highest amplification is provided by SRA3, a QB-784 amplifier by Q-Bit corporation, and will provide 80 $\pm$ 3 dB of gain with a 1 dB compression point of +13 dBm and a 3.0 dB noise figure. The SRA3 is followed by a trimmer that is normally set at -6 dB but has a total trim range from 0 to -20 dB to set the output power level at +5 dBm maximum. The anti-aliasing filter unit employs two operational amplifiers which provide voltage gains of 10 and 5. They are DIP LM-318's.

5. <u>Noise Temperature Calculations</u>

The system gain to the input of the Spectrum Receivers is +26.5 dB. The Spectrum Receivers are capable of analyzing out-of-band signal levels up to -22.5 dBm. RFI signals stronger than this will drive the SRA2 amplifier into non-linear

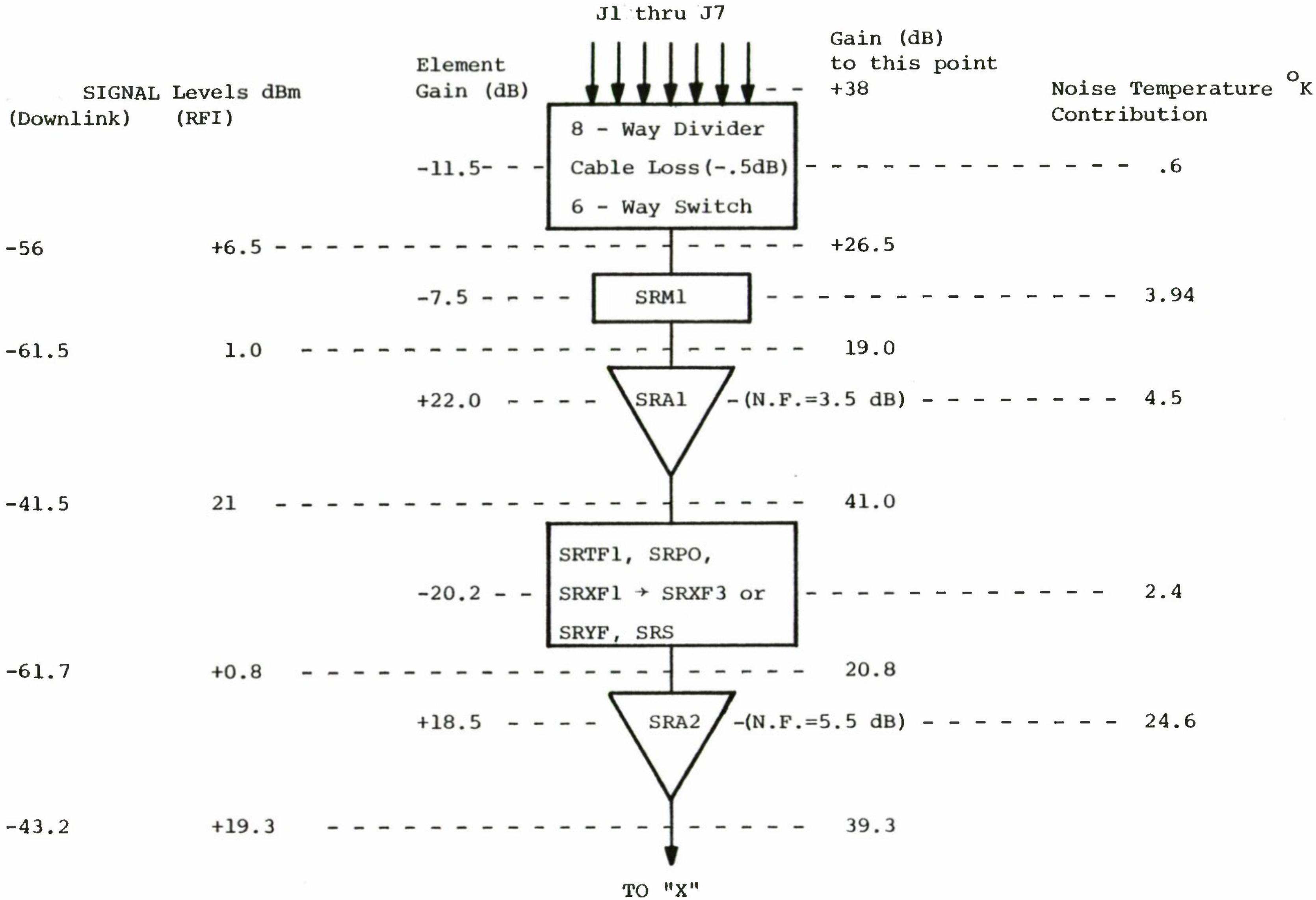



Figure 2.11
Amplification Chain (Page 1 of 2)

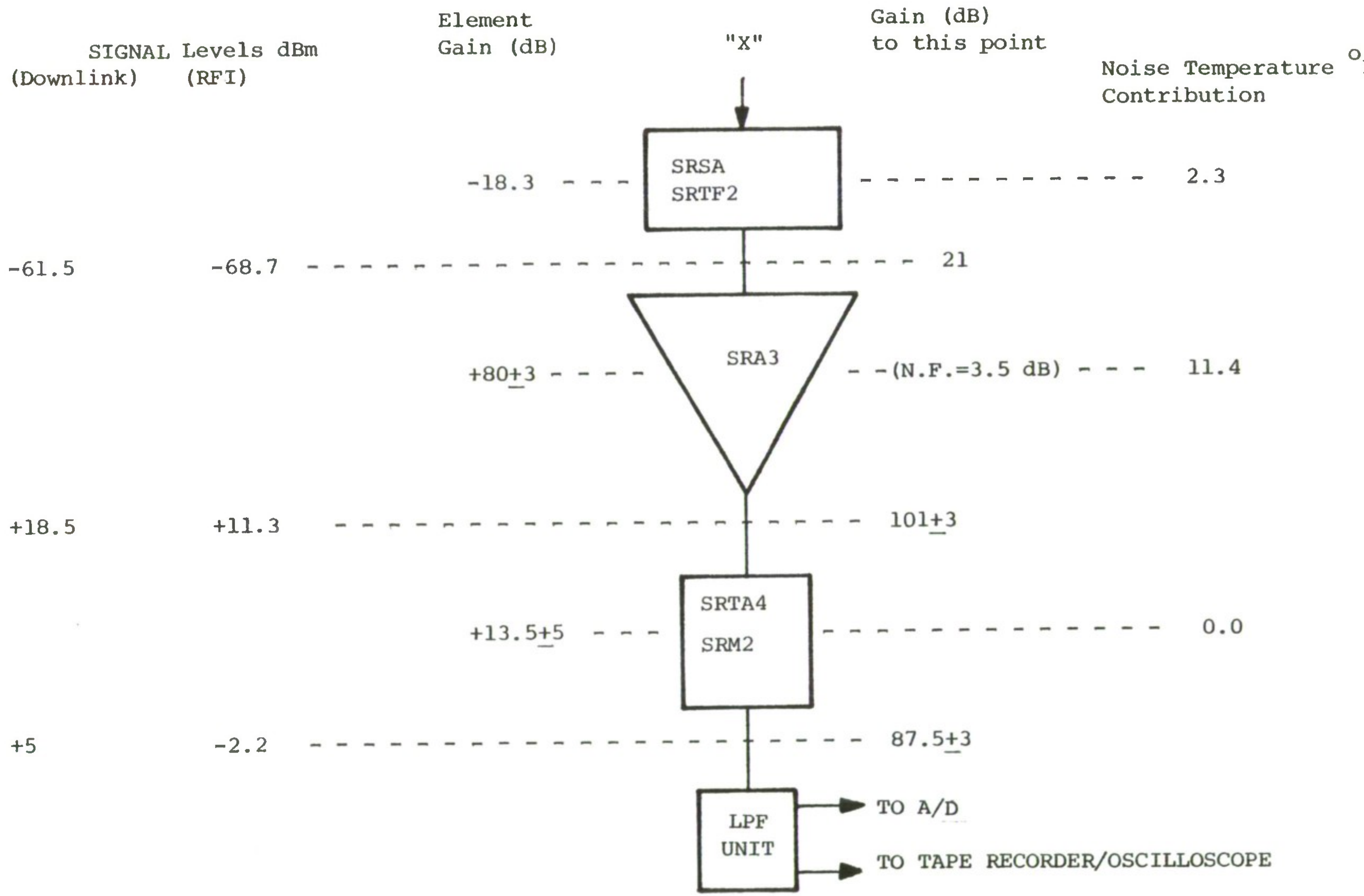



Figure 2.11
Amplification Chain (Page 2 of 2)

operation. The strongest signal level from the satellite's transponder is -85 dBm with the weakest detectable signal being - 135 dBm, a dynamic range of 50 dB provided by the SRSA step attenuator, SRTA4 trimmer, and dynamic range of the A/D converter [2].

Table II gives a comprehensive review of the results of the noise temperature calculations. The calculations begin at the input to the Signal Selection Unit and end at the output of the SRA3 high gain amplifier. Consecutive passive components are lumped together. A noise temperature of 550$^{\circ}$ (K) is estimated to be the system noise temperature to the input of the Signal Selection Unit. Calculations were made using

$$\text{NOISE TEMPERATURE (K)} = \frac{290(F-1)}{G}$$

where

F = Noise Figure contribution of components in dB

and

G = Total Gain to that point in dB.

6. Control of Coaxial Switch SRS, Multiplexer SRMX, and Step Attenuator SRSA

Eight bits of control are required for each Spectrum Receiver for the control of SRS, SRMX, and SRSA. Four bits control the SRS and SRMX simultaneously for bandwidth selection. The coincidental control insures the simultaneous operation of SRXF1 with SRLPF1, SRXF2 with SRLPF2, SRXF3 with SRLPF3, and SRYF with SRLPF4 for maximum reduction of aliasing. The remaining four bits determine the amount of desired step

attenuation to be added between 0 and 88 dB in 8 dB increments.

All control bits are furnished by the Control Bus via an interface panel shown in Figure 2.7. The purpose of the Control Bus is to interface the PDP-11/34 computer to all the digitally programmable devices of the SATCOM Signal Analyzer [3]. TTL control bits for bandwidth selection and selectable attenuation are given in Appendix C. CIB4 has been assigned to provide control bits for the Spectrum Receivers. An example of an octal word and its interpretation is given in Figure 3.4. Operator guidelines for selection of inputs to the Spectrum Receivers are given in Apprndix J.

# III. SIGNAL SELECTION UNIT SSU

## A. GENERAL

The component parts of the Signal Selection Unit are mounted on a 3/16" thick aluminum panel 10-1/2" x 19". Reference is made to the inside and outside of the unit because it is mounted on a swing gate in the rear of a cabinet made by Zero Corporation. The power dividers and one switch are mounted on the outside. On the inside are mounted the remaining seven switches. All inputs, outputs, control and power leads enter the unit on the inside to prevent bunching of leads when opening and closing the swing gate. The swing gate is hinged on the right side facing the back of the cabinet to prevent interference with the outermost door which is hinged on the left.

As in the Spectrum Receivers, the connections between components are made with SMA connectors and RG-223 double-shielded coaxial cables. Connections for control and power of the solid-state coaxial switches by Lorch Electronics are soldered, the control lines coming from a T & B/Ansley ribbon connector and the power lines provided via a 4-pin Amphenol connector for $\pm$ 5 volts and $\pm$ 5 volt returns. The two return lines are soldered together to make a common return. The solid state switches are all TTL compatible and specifications for them are shown in Appendix H.

## B. DESIGN REQUIREMENTS AND CONSIDERATIONS

Following the basic block diagram for the SSU in Figure 1.3 the largest constraint was to mount all the components on a panel 10-1/2 inches high. This was accomplished as is shown in the outside and inside views in Figures 3.1 and 3.2.

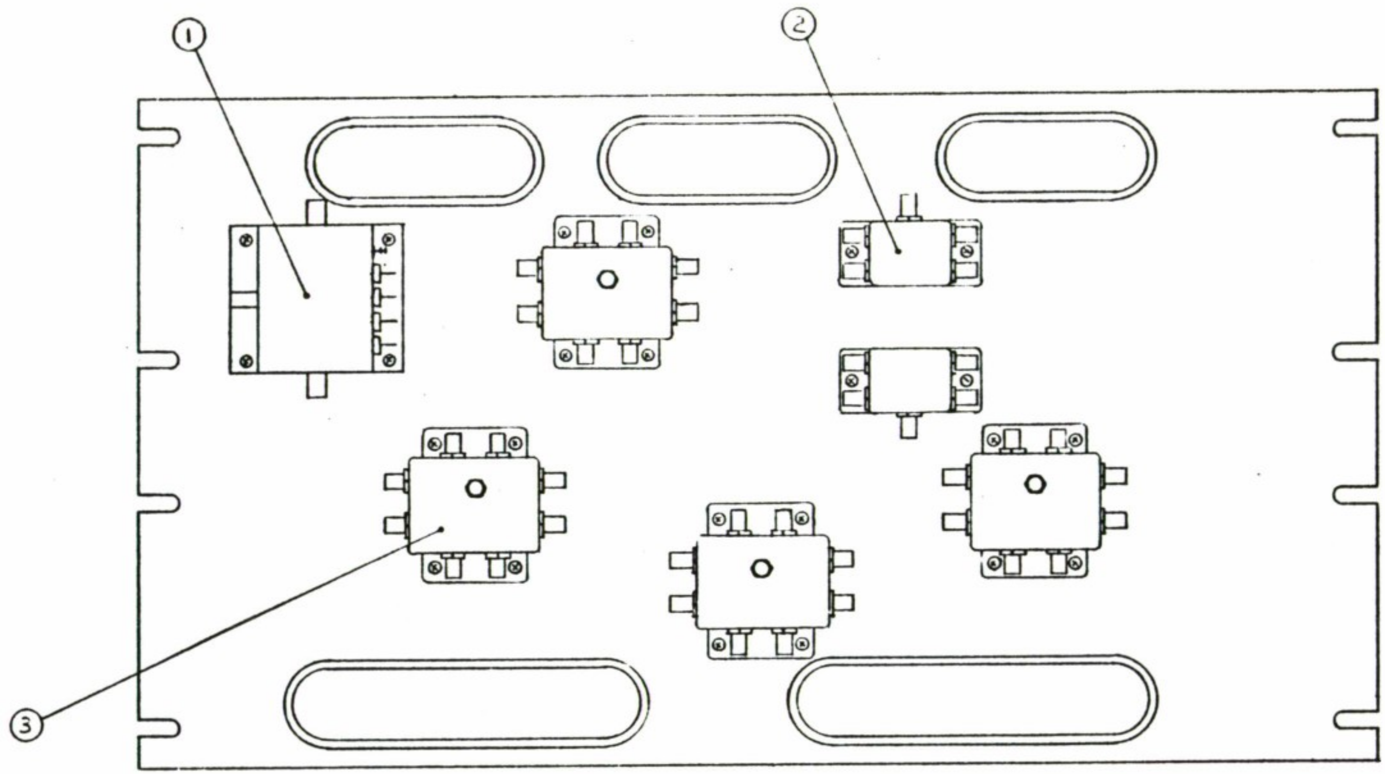
The 4 and 8-way power dividers are provided by Merrimac Industries and have theoretical losses of 6 and 9 dB, respectively. Specifications for the power dividers are given in Appendix K.

The oval cut-outs provide a channel for the coaxial cables to feed through to the opposite side. The cut-outs are lined with a polyethylene flexible grommet for protection of the cables.

The addition of the two-way switch on the outside of the SSU came after a decision to include the transmit capability (XC3) to system 3 shown in Figure 3.3, the SATCOM Signal Analyzer RF Configuration. The XC3 input shares an 8-way divider via the two-way switch with the tape playback input, because the tape playback will not be used all of the time. The XC3 input for analysis is expected to have similar limited use.

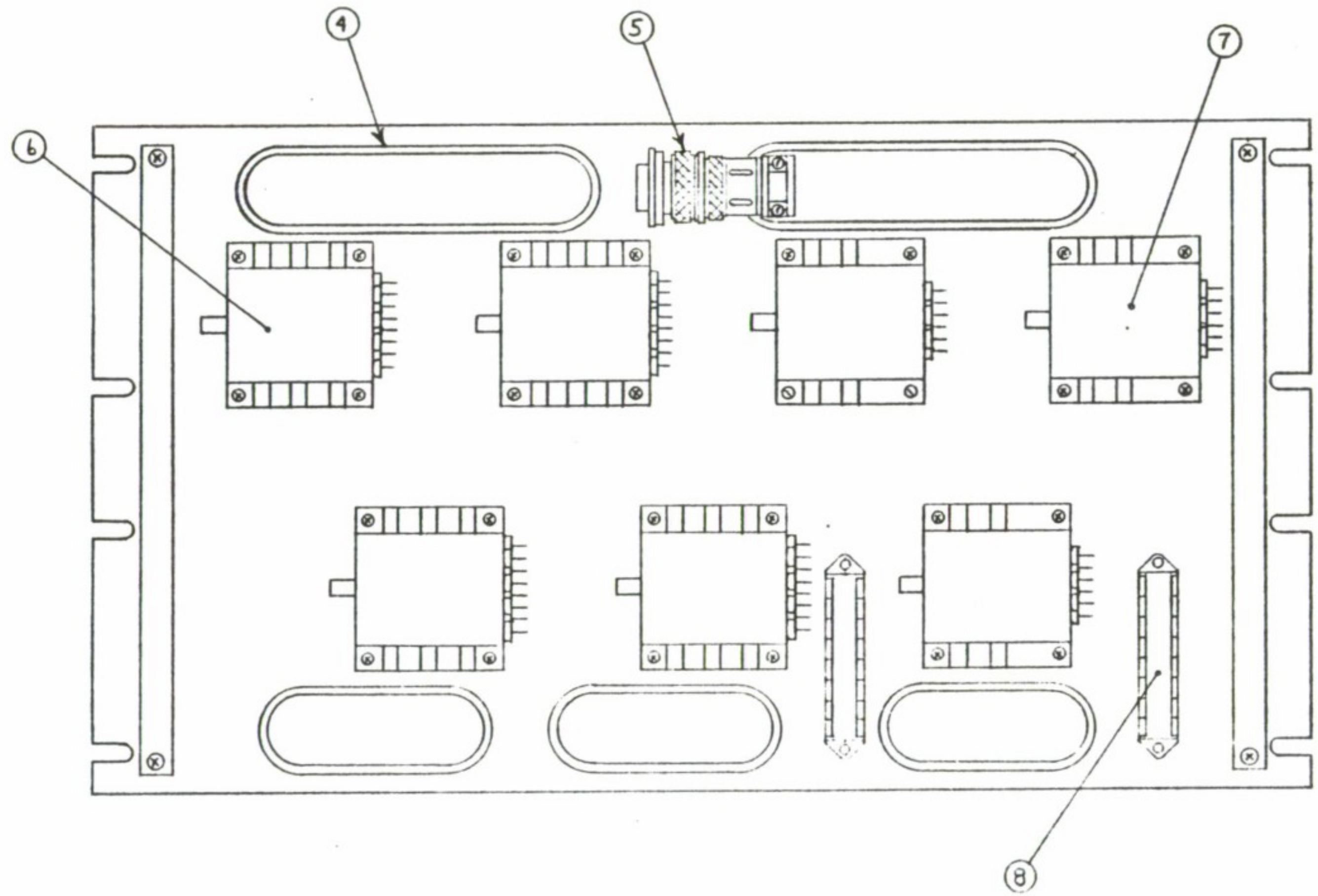
### 1. Control of Coaxial Switches

Any of the seven IF inputs, RCL → RC3, XC1 → XC3, and tape playback to the SSU can be selected by the operator for analysis with receivers R1 thru R7. Control data bits to the SSU come from CIB3 and CIB4. CIB3 and CIB4 are identical boards in the control unit. The operator indirectly selects




1 = SP2T Switch
2 = 4-way Divider
3 = 8-way Divider

Figure 3.1
SIGNAL SELECTION UNIT (outside view)




4 = Grommet Strip
5 = 14-pin power connector
6 = SP6T switch

7 = SP4T switch
8 = 50-pin control connector

Figure 3.2

SIGNAL SELECTION UNIT (inside view)

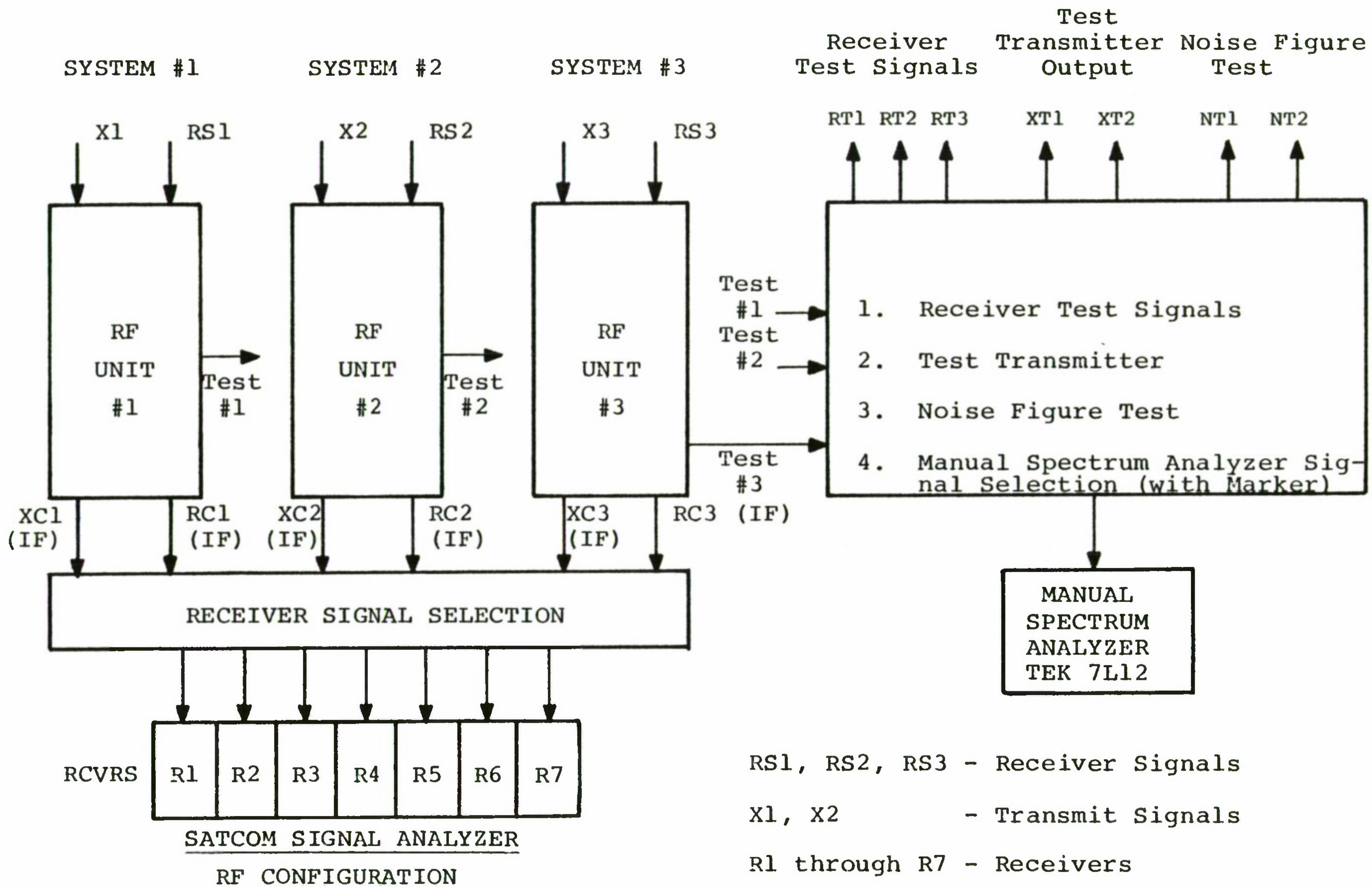



Figure 3.3
SATCOM SIGNAL ANALYZER RF CONFIGURATION

an octal word which corresponds to a desired function. There are four bytes on each CIB, each byte containing eight data bits. In the octal word indirectly selected by the operator, the first four digits correspond to the binary data bits D7, D6, D5, D4, D3, D2, D1, D0, and two "don't cares". The most significant octal digit refers to D7, the second most significant refers to D6, D5, and D4. The third digit refers to D3, D2, and D1, while the fourth refers to D0 and the two "don't cares". The fifth octal digit represents the three most significant bits in the CIB selection S3, S2, and S1. S0, A1, and A0 are taken up by the last digit in the octal word representing the least significant bit in the CIB Board selection and the byte selection, respectively. An example of an octal word selection and its interpretation is shown in Figure 3.4.

Logic interconnection cables are flat ribbon cables terminating in T&B/Ansley female-type socket connectors. CIB ribbon numbers do not correspond one-to-one with the socket connector output numbers. The true correspondence is shown in Appendix B. The control bits for control of the switches are split between CIB3 and CIB4, CIB3 providing data control to switches S1, S2, S3, and S8, and CIB4 providing data control for switches S4, S5, S6, and S7. Program mappings for control by CIB's 3 and 4 are shown in Table V.

Control and ground wires run in bundles down the center of the panel and branch off to their respective switches. An exception to this is S8 which is mounted on the opposite side

An example of an octal word selection by the computer with its binary derivation is:

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 5 | | | 7 | | | 4 | | | 1 | | | 6 | |
| 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | X | X | S3 | S2 | S1 | S0 | A1 | A0 |
| | | Data Bits | | | | | | Always Zero | | | CIB | | | Byte | |

Each byte contains 8 data bits.

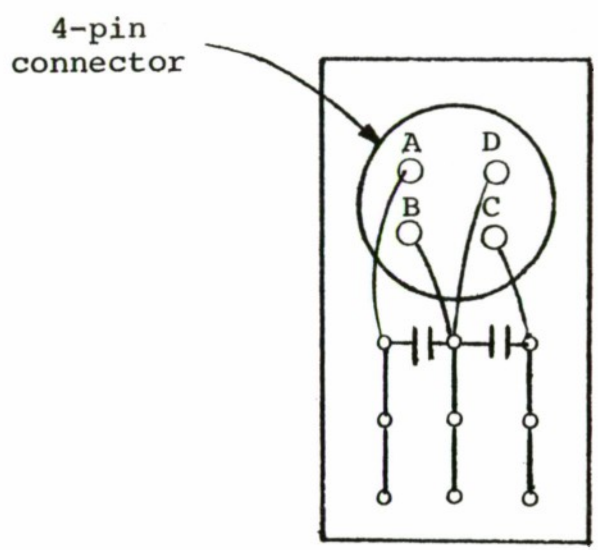
Figure 3.4

OCTAL WORD INTERPRETATION

of the panel from the ribbon connector. Its bundle is run along the edge of the panel. The socket connectors are placed on the inside of the panel to minimize movement of the ribbon during opening of the swing gate.

2. <u>Voltage and Power Supplies</u>

Each switch requires $\pm$ 5 volts and a ground. The 6-way switches require approximately 300 mA, the 4-ways require 240 mA, and the 2-way requires 170 mA. The 4-pin Amphenol connector model MS3102A 14S-2P having only four leads had to be modified to fan-out to provide 24 power supply lines. This connector terminates the power cable to the Signal Selection Unit. Power fan-out is shown in Figure 3.5.




A = +5 VOLTS

B = +5 RETURN

C = -5 VOLTS

D = -5 RETURN

NOTE: Wires from the connector go to posts on the printed circuit board. From the posts the ±5 voltages and returns are distributed to the switches.

Figure 3.5

POWER DISTRIBUTION FANOUT

## IV. CONCLUSIONS

All parts for the Spectrum Receivers have been specified, ordered, and most have been received. Sufficient detail has been provided herein for final construction upon receipt of remaining parts. The Lowpass Filter Unit is 50 percent complete with minimal completion time required after turnover to oncoming students. This Spectrum Receiver design permits multi-bandwidth monitoring with RFI present and improved analysis capability over the current FSM.

All parts for the Signal Selection Unit have been received, tested, and assembled. This unit is 95 percent complete with only the control and power lines to be distributed to the switches.

## APPENDIX A

## COMPONENT IDENTIFICATION

The following symbols have been used as acronyms for a particular electronic component or component group of the Spectrum Receivers (SR).

| SYMBOL | COMPONENT/GROUP |
|---|---|
| SR1→SR4 | Spectrum Receivers Nos. 1 through 4 |
| SRA1→SRA3 | Amplifier Nos. 1 through 3 |
| SRLPF1→SRLPF4 | Low Pass Filter Nos. 1 through 4 |
| SRM1→SRM2 | Mixer Nos. 1 and 2 |
| SRMX | Multiplexer |
| SRPD | Power Divider |
| SRS | Switch |
| SRSA | Step Attenuator |
| SRTA→SRTA4 | Trimmer Attenuator No. 1 through 4 |
| SRTF1→SRTF2 | Tubular Filter Nos. 1 and 2 |
| SRXF1→SRXF3 | Crystal Filter Nos. 1 through 3 |
| SRYF | LC Filter |

The following symbols were used as acronyms for a particular electronic component or component group of the Signal Selection Unit (SSU).

| SYMBOL | COMPONENT/GROUP |
|---|---|
| SSU | Signal Selection Unit |
| SSUPD1→SSUPD6 | Power Divider Nos. 1 through 6 |
| SSUS1→SSUS8 | Coaxial Switch Nos. 1 through 8 |
| SSUC1,SSUC2 | 50-pin control connector |
| SSUC3 | 4-pin power connector |

## APPENDIX B

## CONTROL INTERFACE BOARD RIBBON MAPPING TO 50-PIN T&B/ANSLEY CONNECTORS 609-50M

| RIBBON LINE NO. | CONNECTOR PIN NO. |
|---|---|
| 1 | 1 |
| 2 | 26 |
| 3 | 2 |
| 4 | 27 |
| 5 | 3 |
| 6 | 28 |
| 7 | 4 |
| 8 | 29 |
| 9 | 5 |
| 10 | 30 |
| 11 | 6 |
| 12 | 31 |
| 13 | 7 |
| 14 | 32 |
| 15 | 8 |
| 16 | 33 |
| 17 | 9 |
| 18 | 34 |
| 19 | 10 |
| 20 | 35 |
| 21 | 11 |
| 22 | 36 |
| 23 | 12 |
| 24 | 37 |
| 25 | 13 |
| 26 | 38 |
| 27 | 14 |
| 28 | 39 |
| 29 | 15 |
| 30 | 40 |
| 31 | 16 |
| 32 | 41 |
| 33 | 17 |
| 34 | 42 |
| 35 | 18 |
| 36 | 43 |
| 37 | 19 |
| 38 | 44 |
| 39 | 20 |
| 40 | 45 |
| 41 | 21 |
| 42 | 46 |

CONTROL BOARD RIBBON MAPPING (CONTINUED)

| RIBBON LINE NO. | CONNECTOR PIN NO. |
|---|---|
| 43 | 22 |
| 44 | 47 |
| 45 | 23 |
| 46 | 48 |
| 47 | 24 |
| 48 | 49 |
| 49 | 25 |
| 50 | 50 |

# APPENDIX C

## PROGRAM MAPPING FOR SPECTRUM RECEIVERS

All control interface boards (CIB's) are identical; however, CIB5 has been selected for control of the Spectrum Receivers. The determination of a basic selection decision (see below) by the operator is controlled internally in the form of an octal word. Octal mapping for the Spectrum Receivers is shown in Table III. The octal word is made-up from data and control bits from the Control bus, as shown in Figure 3.4. Format for the binary derivation of an octal word is

D7D6D5D4D3D2D1D0XXS3S2S1S0A1A0.

The X's in the binary word are always zero. Table III describes the determination of the four selection decisions required with the use of the Spectrum Receivers:

(1) Bandwidth (a filter of the main filter bank)/LPF

(2) Step attenuation

(3) Control Interface Board

(4) Spectrum Receiver SR1 → SR4

The data bits D3, D2, D1, and D0 control the DAICO Step Attenuator with attenuation steps of 8, 16, 32 and 32. The data bits D7, D6, D5 and D4 select SRYF1, SRXF3, SRXF2 and SRXF1, respectively. Table IV summarizes the function for each data bit provided by CIB5.

TABLE III

PROGRAM MAPPING FOR SPECTRUM RECEIVERS

| BANDWIDTH (D7D6D5D4) | STEP ATTENUATION (D3D2D1D0) | CIB (S3S2S1S0) | SPECTRUM RECEIVER (A1A0) |
|---|---|---|---|
| 1 = 1 1 1 0 | 0 = 0 0 0 0 | | 1 = 0 0 |
| | 8 = 1 0 0 0 | | |
| 2 = 1 1 0 1 | 16 = 0 1 0 0 | | 2 = 0 1 |
| | 24 = 1 1 0 0 | | |
| 3 = 1 0 1 1 | 32*= 0 0 1 0 | 5 = 0 1 0 1 | 3 = 1 0 |
| | 40*= 1 0 1 0 | | |
| 4 = 0 1 1 1 | 48*= 0 1 1 0 | | 4 = 1 1 |
| | 56*= 1 1 1 0 | | |
| (negative logic switch) | 64 = 0 0 1 1 | | |
| | 72 = 1 0 1 1 | | |
| | 80 = 0 1 1 1 | | |
| | 88 = 1 1 1 1 | | |

* Either D0 or D1 could have been selected "high".

# APPENDIX D

## LOWPASS FILTERS SRLPF1 → SRLPF4 SPECIFICATIONS

The lowpass filters SRLPF1 → SRLPF4 are located in the LPF unit designed for reducing aliasing. The following specifications are required for SRLPF1 → SRLPF4.

| SPECIFICATION | SRLPF1 | SRLPF2 | SRLPF3 | SRLPF4 |
|---|---|---|---|---|
| Ripple(maximum) | ±0.2dB | ±0.2dB | ±0.2dB | ±0.2dB |
| 0.2dB cutoff frequency | 7.2kHz | 58kHz | 186kHz | 800kHz |
| 3.0dB down point | 12 kHz | 97kHz | 310kHz | 1.5MHz |
| 10.0dB down point | 18 kHz | 146kHz | 465kHz | 2.2MHz |

TABLE IV

SPECTRUM RECEIVER DIGITAL CONTROL

| BIT | FUNCTION |
|---|---|
| D7 (MSB) | 1 = BANDWIDTH 4 "OFF" |
| | 0 = BANDWIDTH 4 "ON" |
| D6 | 1 = BANDWIDTH 3 "OFF" |
| | 0 = BANDWIDTH 3 "ON" |
| D5 | 1 = BANDWIDTH 2 "OFF" |
| | 0 = BANDWIDTH 2 "ON" |
| D4 | 1 = BANDWIDTH 1 "OFF" |
| | 0 = BANDWIDTH 1 "ON" |
| D3 | 1 = STEP 1 (8 dB) "ON" |
| | 0 = STEP 1 (8 dB)"OFF" |
| D2 | 1 = STEP 2 (16 dB)"ON" |
| | 0 = STEP 2 (16 dB)"OFF" |
| D1 | 1 = STEP 3 (32 dB)"ON" |
| | 0 = STEP 3 (32 dB)"OFF" |
| D0 (LSB) | 1 = STEP 4 (32 dB)"ON" |
| | 0 = STEP 4 (32 dB)"OFF" |

## APPENDIX E

## CAPACITANCE AND RESISTANCE VALUES FOR LOWPASS FILTERS SRLPF1 → SRLPF3

| | SRLPF1 | SRLPF2 | SRLPF3 |
|---|---|---|---|
| $R_1$ | 100KΩ | 100KΩ | 100KΩ |
| $R_2$ | open | open | open |
| $R_3$ | 34.99KΩ | to be resolved | to be resolved |
| $R_4$ | 4.2KΩ | 599Ω | 200Ω |
| $R_5$ | 4.2KΩ | 599Ω | 200Ω |
| $R_6$ | 10KΩ | 15KΩ | 10KΩ |
| $R_7$ | 10KΩ | 15KΩ | 10KΩ |
| $R_8$ | 5KΩ | 7.5KΩ | 5KΩ |
| $C_1$ | 1326pf | 162pf | to be resolved |
| $C_2$* | - - | 22μf | to be resolved |
| $C_3$* | - - | 2.2μf | to be resolved |

* = electrolytic bypass capacitor

See Figures 2.8 and 2.9 for element positioning

## APPENDIX F

## DOUBLE-BALANCED MIXER SPECIFICATIONS

The SRM1 and SRM2 mixers used in the Spectrum Receivers are model DMM-4-250 built by MERRIMAC INDUSTRIES, INC.

| | |
|---|---|
| Frequency Range | |
| R&L Ports | 5-500 MHz |
| X Port | DC-500 MHz |
| Conversion Loss | 8.0 dB (max.) |
| Isolation (min.) | |
| L to R (to 100 MHz) | 45dB |
| (to 500 MHz) | 40dB |
| L to X (to 100 MHz) | 35dB |
| (to 500 MHz) | 15dB |
| R to X (to 100 MHz) | 20dB |
| (to 500 MHz) | 15dB |
| 1 dB compression point | +8 dBm (min.) |
| Local Oscillator Drive | +17dBm (nominal) |
| Useful Local Oscillator Drive | +10 to +20 dBm |
| Noise Figure | Conversion Loss +1 dB |
| Impedance | 50 ohms |
| Max. Input Power | +24.8 dBm |
| Temperature Range | $-59^{\circ}$ to $100^{\circ}C$ (operating) |

# APPENDIX G

## INTERCONNECTION TABLE FOR SR1→SR4 AND SSU

| UNIT | CONNECTOR | FUNCTION | CONNECTED TO |
|---|---|---|---|
| SR1 | J1 | IF INPUT | SSU J11 |
| SR2 | J1 | IF INPUT | SSU J12 |
| SR3 | J1 | IF INPUT | SSU J13 |
| SR4 | J1 | IF INPUT | SSU J14 |
| SR1→SR4 | J2 | L.O. INPUT | Rockland Synthesizer |
| SR1→SR4 | J3 | CONTROL INPUT | Control Bus |
| SR1→SR4 | J4 | L.O. INPUT | Rockland Synthesizer |
| SR1→SR4 | J5 | BASEBAND OUTPUT | A/D Converter |
| SR1→SR4 | J6 | BASEBAND OUTPUT | Tape Recorder |
| SSU | J1 | IF INPUT | IF Receiver 1 |
| SSU | J2 | IF INPUT | IF Receiver 2 |
| SSU | J3 | IF INPUT | IF Receiver 3 |
| SSU | J4 | IF INPUT | Transmitter 1 |
| SSU | J5 | IF INPUT | Transmitter 2 |
| SSU | J6 | IF INPUT | Transmitter 3 |
| SSU | J7 | IF INPUT | Tape Playback |
| SSU | J8 | IF OUTPUT (RC1) | Test Unit |
| SSU | J9 | IF OUTPUT (RC2) | Test Unit |
| SSU | J10 | IF OUTPUT (RC3) | Test Unit |
| SSU | J11 | IF OUTPUT | SR1 |
| SSU | J12 | IF OUTPUT | SR2 |
| SSU | J13 | IF OUTPUT | SR3 |
| SSU | J14 | IF OUTPUT | SR4 |
| SSU | J15 | IF OUTPUT | AM/FM Receivers |
| SSU | J16 | IF OUTPUT | Frequency Receiver 1 |
| SSU | J17 | IF OUTPUT | Frequency Receiver 2 |

## APPENDIX H

## COAXIAL SWITCH SPECIFICATIONS

The solid state coaxial switches SRS in the Spectrum Receivers and SSUS1→SSUS8 in the Signal Selection Unit are made by LORCH ELECTRONICS. The SRS and SSUS5→SSUS7 are SP4T Model ES-391M, the SSUS1→SSUS4 are SP6T Model ES-393M and the SSUS8 is a SP2T Model ES-387M.

### SPECIFICATIONS COMMON TO ALL SWITCHES

| | |
|---|---|
| TTL COMPATIBLE | |
| TTL "0" = ON OR CLOSED | |
| TTL "1" = OFF OR OPEN | |
| VSWR (MAX.) | 1.5:1 |
| SELF-TERMINATING UNUSED PORTS | |
| IMPEDANCE | 50 ohms |
| INSERTION LOSS (MAX.) | 1 dB |
| ISOLATION (MIN.) | 70 dB |
| 1 WATT NONDESTRUCT | |
| FREQUENCY RANGE | 20-400 MHz |
| SWITCHING TIME | 10 microseconds |

### SPECIFICATIONS UNIQUE TO SP2T

| | |
|---|---|
| DC POWER REQUIRED | +5V at 85 MA (MAX.)<br>-5V at 75 MA (MAX.) |

### SPECIFICATIONS UNIQUE TO SP4T

| | |
|---|---|
| DC POWER REQUIRED | +5V to 170 MA (MAX.)<br>-5V at 150 MA (MAX.) |

### SPECIFICATIONS UNIQUE TO SP6T

| | |
|---|---|
| DC POWER REQUIRED | +5V at 195 MA (MAX.)<br>-5V at 175 MA (MAX.) |

## APPENDIX I

## STEP AND TRIMMER ATTENUATOR SPECIFICATIONS

The trimmer attenuators are made by Merrimac Industries and (Model Arm-1) have the following specifications:

| | |
|---|---|
| Frequency Range | DC to 400 MHz |
| Insertion Loss | 2.0 dB max |
| Trimming Range | 0 to 20 dB |
| Drive Control | Screw/Lock |

---

The 4-step solid-state step attenuators are made by DAICO Industries (Model 10000589) with steps of 8, 16, 32 and 32 dB allowing for an attenuation range of 0 to 88 dB in 8 dB increments.

| | |
|---|---|
| Switching Speed | 1 microsecond (max) |
| Control | TTL |
| Power | +5 v at 35 mA/step, 140 ma total |
| Insertion Loss | .4 dB/step, 1.6 dB total |
| VSWR | 1.35:1 (max) |
| Impedance | 50 ohms |
| Frequency Range | 20 - 300 MHz |
| 1 dB Compression Pt | +13 dBm |

APPENDIX J

DIGITAL PROGRAMMING OF THE SPECTRUM RECEIVERS
AND SIGNAL SELECTION UNIT USING
THE CIB AND PDP-11/34 DR11C

1. Push CNTRL and HALT/SS simultaneously to halt the CPU.
2. Push CNTRL and BOOT simultaneously to obtain monitor on the screen.
3. Type L^167772 * Loads address of C1B-DR11C.
4. TYPE E^ Examines a memory location.
5. TYPE D^XXXXXX *.

   D = Deposit (Load or write an octal work in memory location 167772.
6. By alternating E's and D's one will keep address 167772 constant.
7. To write another octal word return to step 4 and continue.

Note: If E's and D's are NOT alternated, the address (167772) will change and one will not be communicating with the C/B.

Legend:

^ = Space Bar
* = Carraige Return

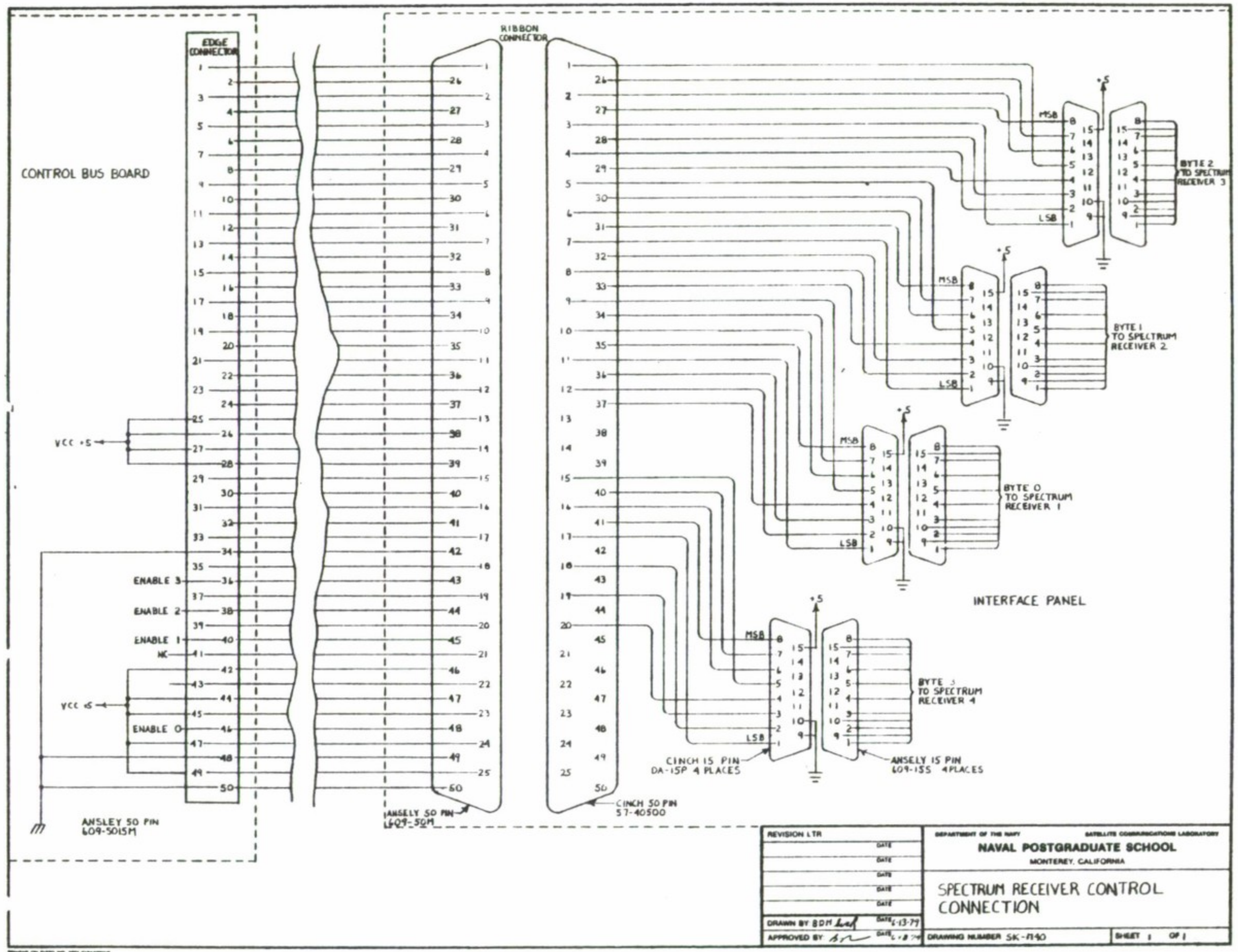



Figure J.1

CONTROL INTERFACE BUS BLOCK DIAGRAM/SCHEMATIC

## APPENDIX K

## POWER DIVIDER SPECIFICATIONS

The 4-way power dividers model PDM-40-110 by Merrimac Industries were used in both the Spectrum Receivers and Signal Selection Unit. Model PDM-80-55 was used only in the Signal Selection Unit.

The 4-way power dividers have the following specifications:

| | |
|---|---|
| Frequency Range | 20 - 200 MHz |
| Theoretical Loss | 6 dB |
| Isolation | 30 dB |
| Insertion Loss | .7 dB |
| Impedance | 50 ohms |
| VSWR | 1.3:1 |
| Connectors | SMA Female |
| Power | 2 watts (max) |

The 8-way power dividers have the following specifications:

| | |
|---|---|
| Frequency Range | 10 - 100 MHz |
| Theoretical Loss | 9 dB |
| Isolation | 30 dB |
| Insertion Loss | 1.0 dB |
| Impedance | 50 ohms |
| VSWR | 1.3:1 |
| Connectors | SMA Female |
| Power | 5 watts (max) |

## APPENDIX L

## PROGRAM MAPPING FOR SIGNAL SELECTION UNIT

The Signal Selection Unit routes signals from RC1 → RC3, XC1 → XC3, and tape playback to the Spectrum, AM/FM, and Frequency Receivers and the Test Unit. CIB's 3 and 4 are the control boards designated for control of the Signal Selection Unit. The determination for selecting the destin- action receiver for an input signal is made in the form of an octal word. The binary equivalent of the octal word is madeup from control and data bits provided by the Control Bus. Format for the binary derivation of the octal word is:

D7D6D5D4D3D2D1D0XXS3S2S1S0A1A0.

The X's are always zero. Table V describes the determination of the decisions required in the selection of desired inputs to the receivers. The situation is exacerbated when selecting the tape playback or XC3 as inputs, because both of these inputs require two octal words, one for selection of the signal input and one for the signal destination. The three selection decisions required for the use of the Signal Sel- ection Unit are:

(1) Input (RC1 → RC3, XC1 → XC3, Tape Playback)

(2) CIB (decision presented in Table V is for CIB3 and CIB4)

(3) Switch (determines the destination receiver (Spectrum, AM/FM, or Frequency Receivers)

TABLE V

PROGRAM MAPPING FOR SIGNAL SELECTION UNIT

| DATA BITS (D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0) | | SWITCHES (S1 → S4) | (S5 → S7) | (S8) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| X | X | 1 | 1 | 1 | 1 | 1 | 0 | = | RC1 | RC1 | XC3 |
| X | X | 1 | 1 | 1 | 1 | 0 | 1 | = | RC2 | RC2 | TAPE |
| X | X | 1 | 1 | 1 | 0 | 1 | 1 | = | RC3 | RC3 | - - - |
| X | X | 1 | 1 | 0 | 1 | 1 | 1 | = | XC3/TAPE | XC3/TAPE | - - - |
| X | X | 1 | 0 | 1 | 1 | 1 | 1 | = | XC1 | - - - | - - - |
| X | X | 0 | 1 | 1 | 1 | 1 | 1 | = | XC2 | - - - | - - - |

| SWITCH (S1 → S8) | CIB (S3S2S1S0) | BYTE (A1A0) |
|---|---|---|
| S1 | 0 0 1 1 | 0 0 |
| S2 | 0 0 1 1 | 0 1 |
| S3 | 0 0 1 1 | 1 0 |
| S4 | 0 1 0 0 | 0 0 |
| S5 | 0 1 0 0 | 0 1 |
| S6 | 0 1 0 0 | 1 0 |
| S7 | 0 1 0 0 | 1 1 |
| S8 | 0 0 1 1 | 1 1 |

## APPENDIX M

## SIGNAL SELECTION DIGITAL CONTROL

The Signal Selection Unit requires two CIB's to satisfy the requirement of 38 bits. CIB3 and CIB4 are selected for control of the Signal Selection Unit. The following summarizes the function of each data bit. Where "or" is used in the table below, another octal word has preceded this word specifying one of the J6 or J7 inputs as shown in Appendix L.

| CIB | BYTE | Bit | Function |
|---|---|---|---|
| 3 | 0 | D7 | Not Used |
| 3 | 0 | D6 | Not Used |
| 3 | 0 | D5 | 1 = J5 Input "OFF" to J11<br>0 = J5 Input "ON" to J11 |
| 3 | 0 | D4 | 1 = J4 Input "OFF" to J11<br>0 = J4 Input "ON" to J11 |
| 3 | 0 | D3 | 1 = J6 or J7 "OFF" to J11<br>0 = J6 or J7 "ON" to J11 |
| 3 | 0 | D2 | 1 = J3 Input "OFF" to J11<br>0 = J3 Input "ON" to J11 |
| 3 | 0 | D1 | 1 = J2 Input "OFF" to J11<br>0 = J2 Input "ON" to J11 |
| 3 | 0 | D0 | 1 = J1 Input "OFF" to J11<br>0 = J1 Input "ON" to J11 |
| 3 | 1 | D7 | Not Used |
| 3 | 1 | D6 | Not Used |
| 3 | 1 | D5 | 1 = J5 Input "OFF" to J12<br>0 = J5 Input "ON" to J12 |
| 3 | 1 | D4 | 1 = J4 Input "OFF" to J12<br>0 = J4 Input "ON" to J12 |
| 3 | 1 | D3 | 1 = J6 or J7 "OFF" to J12<br>0 = J6 or J7 "ON" to J12 |
| 3 | 1 | D2 | 1 = J3 Input "OFF" to J12<br>0 = J3 Input "ON" to J12 |
| 3 | 1 | D1 | 1 = J2 Input "OFF" to J12<br>0 = J2 Input "ON" to J12 |
| 3 | 1 | D0 | 1 = J1 Input "OFF" to J12<br>0 = J1 Input "ON" to J12 |
| 3 | 1 | D1 | 1 = J2 Input "OFF" to J12<br>0 = J2 Input "ON" to J12 |
| 3 | 1 | D0 | 1 = J1 Input "OFF" to J12<br>0 = J1 Input "ON" to J12 |

APPENDIX M (continued)

| CIB | Byte | Bit | Function |
|---|---|---|---|
| 3 | 2 | D7 | Not Used |
| 3 | 2 | D6 | Not Used |
| 3 | 2 | D5 | 1 = J5 Input "OFF" to J13<br>0 = J5 Input "ON" to J13 |
| 3 | 2 | D4 | 1 = J4 Input "OFF" to J13<br>0 = J4 Input "ON" to J13 |
| 3 | 2 | D3 | 1 = J6 or J7 "OFF" to J13<br>0 = J6 or J7 "ON" to J13 |
| 3 | 2 | D2 | 1 = J3 Input "OFF" to J13<br>0 = J3 Input "ON" to J13 |
| 3 | 2 | D1 | 1 = J2 Input "OFF" to J13<br>0 = J2 Input "ON" to J13 |
| 3 | 2 | D0 | 1 = J1 Input "OFF" to J13<br>0 = J1 Input "ON" to J13 |
| 3 | 3 | D7 | Not Used |
| 3 | 3 | D6 | Not Used |
| 3 | 3 | D5 | Not Used |
| 3 | 3 | D4 | Not Used |
| 3 | 3 | D3 | Not Used |
| 3 | 3 | D2 | Not Used |
| 3 | 3 | D1 | 1 = J7 Input "OFF" to S8 OUTPUT<br>0 = J7 Input "ON" to S8 OUTPUT |
| 3 | 3 | D0 | 1 = J6 Input "OFF" to S8 OUTPUT<br>0 = J6 Input "ON" to S8 OUTPUT |
| 4 | 0 | D7 | Not Used |
| | | D6 | Not Used |
| 4 | 0 | D5 | 1 = J5 Input "OFF" to J14<br>0 = J5 Input "ON" to J14 |
| 4 | 0 | D4 | 1 = J4 Input "OFF" to J14<br>0 = J4 Input "ON" to J14 |
| 4 | 0 | D3 | 1 = J6 or J7 "OFF" to J14<br>0 = J6 or J7 "ON" to J14 |
| 4 | 0 | D2 | 1 = J3 Input "OFF" to J14<br>0 = J3 Input "ON" to J14 |
| 4 | 0 | D1 | 1 = J2 Input "OFF" to J14<br>0 = J2 Input "ON" to J14 |
| 4 | 0 | D0 | 1 = J1 Input "OFF" to J14<br>0 = J1 Input "ON" to J14 |
| 4 | 1 | D7 | Not Used |
| 4 | 1 | D6 | Not Used |
| 4 | 1 | D5 | Not Used |
| 4 | 1 | D4 | Not Used |
| 4 | 1 | D3 | 1 = J6 or J7 "OFF" to J15<br>0 = J6 or J7 "ON" to J15 |
| 4 | 1 | D2 | 1 = J3 Input "OFF" to J15<br>0 = J3 Input "ON" to J15 |

| CIB | Byte | Bit | Function |
|---|---|---|---|
| 4 | 1 | D1 | 1 = J2 Input "OFF" to J15<br>0 = J2 Input "ON" to J15 |
| 4 | 1 | D0 | 1 = J1 Input "OFF" to J15<br>0 = J1 Input "ON" to J15 |
| 4 | 2 | D7 | Not Used |
| 4 | 2 | D6 | Not Used |
| 4 | 2 | D5 | Not Used |
| 4 | 2 | D4 | Not Used |
| 4 | 2 | D3 | 1 = J6 or J7 "OFF" to J16<br>0 = J6 or J7 "ON" to J16 |
| 4 | 2 | D2 | 1 = J3 Input "OFF" to J16<br>0 = J3 Input "ON" to J16 |
| 4 | 2 | D1 | 1 = J2 Input "OFF" to J16<br>0 = J2 Input "ON" to J16 |
| 4 | 2 | D0 | 1 = J1 Input "OFF" to J16<br>0 = J1 Input "ON" to J16 |
| 4 | 3 | D7 | Not Used |
| 4 | 3 | D6 | Not Used |
| 4 | 3 | D5 | Not Used |
| 4 | 3 | D4 | Not Used |
| 4 | 3 | D3 | 1 = J6 or J7 "OFF" to J17<br>0 = J6 or J7 "ON" to J17 |
| 4 | 3 | D2 | 1 = J3 Input "OFF" to J17<br>0 = J3 Input "ON" to J17 |
| 4 | 3 | D1 | 1 = J2 Input "OFF" to J17<br>0 = J2 Input "ON" to J17 |
| 4 | 3 | D0 | 1 = J1 Input "OFF" to J17<br>0 = J1 Input "ON" to J17 |

# APPENDIX N

## CRYSTAL FILTER SPECIFICATIONS

The crystal filters used in the Spectrum Receivers SR1 → SR4 are made by DAMON Corporation. The crystal filters are numbered SRXF1 → SRXF3 which corresponds to their channel number, SRXF1 (Model 7475A) passing the narrowest bandwidth for best resolution in Channel 1, SRXF2 (Model 7474A) forms Channel 2, and SRXF3 (Model 7473A) forms Channel 3.

| SPECIFICATIONS COMMON TO ALL FILTERS | |
|---|---|
| Passband Ripple | $\pm$ .25 dB |
| Impedance | 50 ohm |
| Connectors | SMA Female |
| Insertion Loss (max) | 8.0 dB |
| VSWR (max) | 1.5:1 |
| Maximum Input RF Power (non-destruct) | +18 dBm |

SPECFICATIONS UNIQUE TO EACH FILTER

| | SRXF1 | SRXF2 | SRXF3 |
|---|---|---|---|
| Nominal Center Frequency (MHz) | 29.9955 | 29.966 | 29.895 |
| Lower 0.5 dB Point (max) | 29.9935 | 29.950 | 29.840 |
| Upper 0.5 dB Point (min) | 29.9975 | 29.982 | 29.950 |
| Lower 60 dB Point (max) | 29.9895 | 29.918 | 29.7575 |
| Upper 60 dB Point (min) | 30.0015 | 30.014 | 30.0325 |
| Spurious Response (max) (within 3 MHz of center frequency (dB)) | -50 | -60 | -50 |

## APPENDIX O

## TUBULAR FILTER SPECIFICATIONS

The tubular filters in the Spectrum Receivers are built by K & L Microwave, Incorporated and were selected primarily for their frequency stability and low cost. SRTF1, Model 6B114, 6-section filter and SRTF2, Model 2B340, has 2 sections.

| Specification | SRTF1 | SRTF2 |
|---|---|---|
| .25 dB Bandwidth | 800 kHz | - |
| .5 dB Bandwidth | - | 3.0 MHz |
| Center Frequency (MHz) | 29.6 | 29.6 |
| Insertion Loss (dB) | 3.5 | 0.7 |
| Connectors | SMA Female | SMA Female |
| 60 dB Bandwidth(max) | $f_c \pm 3.0$MHz | $f_c \pm 5.0$ MHz |

## APPENDIX P

## L.C. FILTER SRYF SPECIFICATIONS

The SRYF filter underwent several iterations of production types due to its high "Q" and complex tuning requirements. The final version will be a lumped-component filter, Model 1850 with the following passband responsible for bandwidth 4.

| | |
|---|---|
| Center Frequency (MHz) | 29.5 |
| Insertion Loss | 9.0 dB |
| Impedance | 50 ohms |
| Passband Ripple | $\pm$.25 dB |
| VSWR | 1.5:1 |
| Lower .5 dB Down Point (max) | 29.2 MHz |
| Upper .5 dB Down Point (min) | 29.8 MHz |
| Lower 35 dB Down Point (max) | 28.8 MHz |
| Upper 35 dB Down Point (min) | 30.2 MHz |
| Connectors | SMA Female |

# APPENDIX Q

## SR1 → SR4 SPECTRUM RECEIVER PARTS LIST

| | |
|---|---|
| SRA1 | Q-BIT QB-300 Amplifier, Gain 22 dB |
| SRA2 | ANZAC AM-105 Amplifier, Gain 19 dB |
| SRA3 | Q-BIT QB-784 Amplifier, Gain 80 dB |
| SRC1 | Amphenol MS3102 A-22-19P, 14-pin connector |
| SRC2 | TRW DA-15P 15-pin connector |
| SRLPFU | Circuit board for filters |
| F1AF1 | DATEL FLT-U2 Universal Hybrid active filter |
| F1C1 | 1320 pf capacitor, 1 percent |
| F1R1 | 100 KΩ resistor, 1 percent |
| F1R3 | 34.99 KΩ resistor, 1 percent |
| F1R4,R5 | 4.2 KΩ resistor, 1 percent |
| F1R6,R7 | 10 KΩ resistor, 1 percent |
| F1R8 | 5 KΩ resistor, 1 percent |
| F2AF1 | DATEL FLT-U2 Universal Hybrid active filter |
| F2C1 | 165 pf capacitor, 1 percent |
| F2C2 | to be resolved |
| F2C3 | to be resolved |
| F2R1 | 100 KΩ resistor, 1 percent |
| F2R3 | to be resolved |
| F2R4,R5 | 599Ω resistor, 1 percent |
| F2R6,R7 | 15 KΩ resistor, 1 percent |
| F2R8 | 7.5 KΩ resistor, 1 percent |
| F3AF1 | DATEL FLT-U2 Universal Hybrid active filter |
| F3C1 | to be resolved |
| F3C2 | to be resolved |
| F3C3 | to be resolved |
| F3C4 | to be resolved |
| F3R1 | 100 KΩ resistor, 1 percent |
| F3R3 | to be resolved |
| F3R4,R5 | 200Ω resistor, 1 percent |
| F3R6,R7 | 10 KΩ resistor, 1 percent |
| R8 | 5 KΩ resistor, 1 percent |
| F4 | TTE J1018 Lowpass Filter |
| MX1 | National CD4051BE Multiplexor, 8-bit |
| OA1 | LM318 operational amplifier, voltage gain 10 |
| OA2 | LM318 operational amplifier, voltage gain 5 |
| OA3,4 | amplifier, voltage gain 1 |
| SRM1,M2 | Merrimac DMM-4-250 mixer |
| SRPD | Merrimac PDM-40-110 divider |
| SRS | Lorch ES-391M Switch, SP4T |
| SRSA | DAICO 100005089-4-A-8,16,16,32 step-attenuator |
| SRTA1,TA2, TA3, TA4 | - Merrimac ARM-1 Trimmer Attenuator, 0-20dB |
| SRTF1 | K&L microwave 6B114-29.6/X0.8-0 Bandpass filter |
| SRTF2 | K&L microwave 2B340-29.6/X3.0-0 Bandpass filter |
| SRXF1 | Damon 7475A Crystal Filter |
| SRXF2 | Damon 7473A Crystal Filter |
| SRXF3 | Damon 7473A Crystal Filter |
| SRYF | K&L Microwave 12B50-29.5/X0.6-0 Bandpass Filter |

APPENDIX R

SSU SIGNAL SELECTION UNIT PARTS LIST

| Item | Description |
|---|---|
| SSUC1, SSUC2 | Amphenol 57-40500 Connector, 50-pin |
| SSUC3 | Amphenol MS3102A 145-2P Power Connector, 4-pin |
| SSUPD1 → SSUPD4 | Merrimac PDM-80-55 Power Divider, 8-way |
| SSUPD5, SSUPD6 | Merrimac PDM-40-110 Power Divider, 4-way |
| SSUS1 → SSUS4 | Lorch ES-393M Switch SP6T |
| SSUS5 → SSUS7 | Lorch ES-391M Switch SP4T |
| SSUS8 | Lorch ES-387M Switch PS2T |
| SSUX | ICO RALLY GSPC-4 Strip Grommet |

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